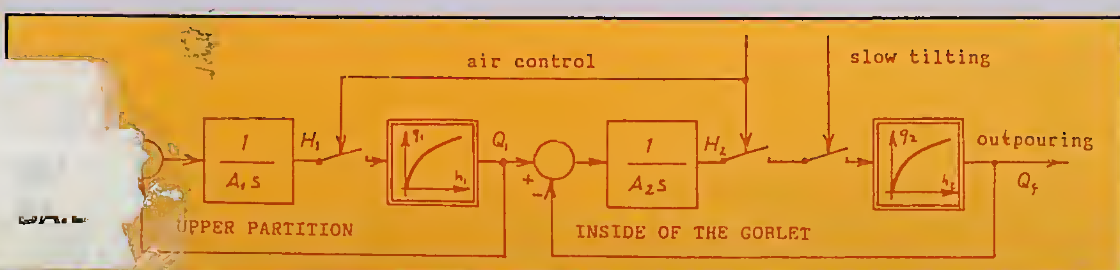
RESEARCH CENTRE FOR ISLAMIC HISTORY, ART AND CULTURE

"KITĀB AL-ḤIYAL" OF BANŪ MŪSĀ BIN SHĀKIR



RESEARCH CENTRE FOR ISLAMIC
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(IRCICA)

THE BOOK

"KITĀB AL-ḤIYAL" OF BANŪ MŪSĀ BIN SHĀKIR

interpreted in sense of modern system and control engineering

by

Atilla BİR

Istanbul
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Studies and Sources
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The Book "Kitâb al-Hiyal"
Banū Mûsâ bin Shâkir
Interpreted in Sense of
Modern System and Control Engineering

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edited by
Ekmeleddin İhsanoğlu

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PREFACE

This new publication in IRCICA's series of "**Studies and Sources on the History of Science**" highlights one of the outstanding Muslim contributions of the past in the field of mechanical sciences. In this work, **Dr. Atilla Bir** interprets and analyses "**Kitāb al-Ḥiyal**" **by Banū Musa bin Shākir** from the point of view of modern systems and control engineering.

Kitāb al-Ḥiyal is an interesting work on magic cups, automatic control mechanisms, oil, oil lamps, fountains, a bellow and an elevator. The work was first partly translated and interpreted into German by Eilhard Wiedemann and F.Hauser. The importance and the originality of Kitāb al-Ḥiyal in the history of the Automatic Control has been earlier pointed out by Otto Mayr. A complete English translation and a wide study of the work is due to Donald R. Hill. And more recently Dr. Ahmad Y. Al-Hassan has edited the whole text and provided notes on it. The work was published by the Institute of the History of Arabic Science at the University of Aleppo, 1981. Today, through the incomplete manuscripts and the fragments found in various libraries, it is known that there must be at least one hundred systems in the original work.

Muḥammed, Aḥmad and al-Ḥassan were scholars known as Bānū Mūsā Brothers in 9th century Baghdad. They won recognition as eminent figures of mathematical sciences in the ᶜAbbāsid period. It is generally accepted that "Kitāb al-Ḥiyal" was written by Aḥmad who was the one most interested in technical subjects. A total of 100 devices are taken up and explained in great detail in this book. 73 of these are related to trick vessels and the others consist of 15 automatic control systems, 7 water jets, 3 oil lamps, one bellow and one lifting mechanism system. Their application is generally based on aerostatic and hydrostatic pressure principles; the systems are more advanced compared to similar hellenistic examples. Some of the command systems and automatic control mechanisms comprised in the book would even satisfy contemporary technologic requirements. The book provides the first examples of various mechanic elements, technical drawings, logic and command systems and especially automatically controlled systems. It can be considered as a continuation and development of "Pneumatica" by Philo of Byzantium and Mechanics by Heron of Alexandria. Its influence on subsequent works reached a peak with the variety of clocks and other automatic tools contained in the work "Kitab al-Hiyal" written by al-Jazari in the beginning of 13th century. The Renaissance technology owes much to these pioneering contributions.

This book is presented in three chapters. In the first chapter, the lives of the Banū Mūsā brothers, and their relations to the caliphs are given, and then the knowledge on the "ingenious devices" and especially on Kitāb al-Ḥiyal is outlined. In the second chapter, the basic motifs and the models forming the systems are examined. In the third and last chapter the systems are described and for each model, a block diagram is derived.

The analysis in "Kitāb al-Ḥiyal" refers essentially to the patterns used in the devices presented. A limited number of patterns are used repetitively and constitute the structural basis of all the tools. These patterns are similar to the elements in modern electronic circuits. Different combinations of these elements perform different functions within the systems. Particularities of the elements are examined and their mathematical models are developed in the book, to obtain the best solutions. This approach is very much in accordance with the principles of modern systems analysis and makes the book appealing especially for engineers.

In his study Dr. Atilla Bir examines these devices, taking each of them as a system and with respect to their above-mentioned characteristics. First, he determines the patterns used in the models. Then, combining the models based on various logical relationships and linear and non-linear blocks, he obtains the corresponding block diagrams. By means of these diagrams and approximations, he develops a mathematical model to establish the workings of the systems and explain their behaviour.

Illustrations pertaining to the models have been reproduced from the manuscript found in the Library of Topkapı Palace Museum in Istanbul (no. A 3474); this is the oldest and most comprehensive copy of the work. Drawings and models which were not included in that manuscript were taken from manuscript copies found at Biblioteca Apostolica Vaticana (no. 317), "Orientabteilung der Staatsbibliothek Preuissischer Kulturbesitz Berlin, Catalogue von Ahlward" (no. 5562) and Gotha Catalogue von Pertsch (no. 1349).

Works dealing with technical and mechanical subjects are few in the Islamic science, as it was in ancient science. Major works in this field have already been studied and published by various scholars and historians of science. For those who are interested in the current state of research in this area, a recent survey by Donald R. Hill, and two comprehensive books are recommended: Hill, D.R., **Mechanical Technology in Islam-Current State of Research: Autumn 1989,** (unpublished); and, **A History of Engineering in Classical and Medieval Times,** Croom Helm, London, 1984 and **Islamic Technology: an illustrated history** (with Ahmad Y. Al-Hassan), UNESCO and Cambridge University Press, 1986.

As the brief presentation above would reveal, this work reflects a new approach and methodology in history of science studies. It analyses medieval Islamic science from the viewpoint of modern scientific knowledge. IRCIÇA is pleased to publish this work and hopes that it will meet interest among concerned circles like previous books in the same series, such as the ''Catalogue of Islamic Medical Manuscripts'', ''Ottoman Scientific and Professional Associations'' and the ''Annotated Bibliography of Early printed Turkish books on Chemistry''.

I take this opportunity to warmly congratulate Dr. Atilla Bir for his valuable contribution to studies on the History of Science and wish him continual success. I also thank the staff of both IRCICA and its printing house and especially Dr. Hidayet Nuhoğlu for their contributions in the composition, graphic works and printing of the book.

Ekmeleddin İhsanoğlu
Director General, IRCICA

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This book inspired by the encouragements of Prof. Dr. Kâzım Çeçen, to whom I wduld like to state my sincere gratitudes and is published by the 'Research Centre for Islamic History, Art and Culture.' I received great help and understanding from the Director General of the Centre Prof. Dr. Ekmeleddin İhsanoğlu, to whom I would like to express my deepest thanks. I am also grateful to the staff of IRCICA who extended their cooperation in the preparation und publication of the book. At last I wish to express my deepest feeling for the support and understanding of my wife, thank my assistant Mrs. Müjde Güzelkaya for carefully reading and correcting the text, and Mrs. Aydan Eksin for the high quality of the typescript for which I record my continuing gratitude.

İstanbul, March 1990

CHAPTER I
INTRODUCTION

1. THE LIFE AND WORKS OF THE BANŪ MŪSĀ BROTHERS [6, 8, 14, 15, 16, 17, 18, 19]

During the reign of the Abbāsid Caliph al-Ma'mūn (813-833) and the succeeding caliphs, the three sons of Mūsā bin *Sh*ākir, known as the Banū (sons of) Mūsā, played an important role in the development of mathematical sciences. Their renown and influence lies not only in their scientific works but also in their special efforts in translating the Greek scientific texts of the Hellenistic period into Arabic. They devoted much of their wealth and energy to the quest and to the translation of the works of ancient writers. The name of the brothers were Muḥammed, Aḥmad and Ḥasan. The sources do not give much information on the dates of their births and deaths. Since they are always mentioned in that order, giving the order of seniority to Moḥammed, we may accept that he is the oldest, and Ḥasan is the youngest of the brothers. It is known that Moḥammed died in January 873 (Rabi I 259); if one accepts him to be 70 years of age at the time of his death, he should have been born around the year 803. Considering this, during the reign of Ma'mūn, Moḥammed should have been a youth between 10 and 30 years of age. He could hardly have been dead earlier because the youngest brother al-Ḥasan was already a brilliant geometrician in the time of al-Ma'mūn's caliphat.

Knowledge about the life of Mūsā bin *Sh*ākir, the father of the brothers, is contradictory. He is said to be a robber on the roads of *Kh*urāsān in his youth. But, it is also said that he was a very able and active man. While Ma'mūn was residing at Marw in *Kh*urāsān during the caliphate of his brother Emin (809-813) Mūsa bin *Sh*ākir started to live honestly in close companionship of al-Ma'mūn and became to be a noted astronomer and geometrician. In those times knowledge in the mentioned sciences was in such a dimension to be comprehended in a short time by an able and an intelligent person. Also the Arab's élan in working and developing these sciences begins henceforth. As for the narration, Ma'mūn had seen Aristotle in his dream telling him about the importance of philosophy. It is told that this is the reason for the

Caliph supporting the sciences and becoming the patron of scientists.

After the death of Mūsa bin *Sh*ākir, al-Ma'mūn, who cared for the Banū Mūsā brothers, . entrusted Ishāk bin İbrāhim with their guardianship. The famous astronomer and astrologer Yaḥyā bin Abī Manṣūr became their tutor. Thus, the Mūsā brothers during their education had the possibility to study deeply into the subjects for which they had talent and interest.

The life of Banū Mūsā brothers was as simple as Ma'mūn's close circle taken from Marw to Baghdad in 813. But, soon after the death of al Ma'mūn their lives became luxurious. The wealth and influence of the brothers developed with the favors of the caliphs and the sources of income charged to their names. They devoted much of their wealth to the quest of the works of ancient writers, and sent missions to Byzantium to seek out such material, paid a group of translators to translate into Arabic and spent so much energy on the development of sciences. This attitude served as a model for others such as Qusta bin Lūqā. Muḥammed is said to have made a journey to Anatolia for this reason and brought back with him, from Harran to Baghdad, one of the most famous scientists and a renowed translator of Islam, *Th*ābit bin Qurrā. The brothers used to pay about five hundred dinars a month to a group of translators who translated the collected works in the House of Wisdom.

The brothers' interest and ability for geometry, ingenious devices, music and astronomy was not always of the same level. Among them Abu Ja'far Muḥammed was the most influential; it is said that he had known the works of Euclid and Ptolemy, that his knowledge in the field of mathematics, astronomy, logic and philosophy was extensive. Aḥmed's talent was in technical matters. The books on the construction of ingenious devices (hiyal) and musical automation must be his work. Ḥasan was a brilliant geometrician. Muḥammed was also highly active in politics. They had mostly lived together, being active during various caliphs and sociable in today's sense.

The biographical and historical works summarize their relations with various caliphs as such:

a) **Ma'mūn** (813-833): As to the will of Mūsā bin *Sh*ākir this caliph was the guardian of the brothers. The first scientific mission of the Banū Mūsā brothers was given by this caliph. The ancient writers determined the circumference of the world as 25000 miles. To prove this they had gone to the desert of al-Sinjar in northern Irāq. They measured the altitude of the Pole Star from a base point, then by the aid of marking pegs and a rope they moved north till the altitude of the star changed one degree. They repeated the same measurement towards the South. Then moving to al-Kûfa in southern Irāq they repeated the process. The value they calculated at the end was 66 2/3 miles for one degree of latitude, from which they found the circumference of the Earth being 24000 miles.

b) **Mu'tas'im** (833-842): Even though one of the sons of Mu'tas'im was trained by Ahmad, their relations with this caliph are obscure. Their disgust against al-Kindī must have taken root from this time.

c) **Wāsık** (842-847): Various events about Muḥammed are told in this epoch. It is noted that Muhammed was sent to the cave of seven sleepers and to Tarjan, the king of Caspian, by the orders of the caliph to observe a certain wall. The caliph had called together the famous astrologers of the country a short while before his death (847). Considering the positions of the stars and the birth date of the caliph they decided that Wāsık had a further 50 years to live, but he died 5 days after this event. Muhammed was present among this council of astrologers.

d) **Mutawakkil** (847-861): The brothers were very active during the reign of this caliph. The caliph himself was interested in ingenious devices and asked the Banū Mūsā brothers to help him and write on this subject. But, as seen in the lives of others who have gone into close contact with the caliph, this was a dangerous matter. The caliph assigned the brothers some land at Balkuwara near Samara. In the year of 860, he ordered the brothers and the architects to find land favorable to build a new city. At the place called Mahuza the new city of Mutawakkil was built. But, the appropriation was insufficient to build the palace of Ja'farriya near the city. Nagah, the advisor of the caliph, suggested that the money should be collected from Muḥammed and Aḥmad bin Mūsā together with eighteen other rich men of the country.

A short time before his death, the caliph wanted the construction of the al-Ja'fariyya canal and ordered the Mūsā brothers to be responsible the work. The brothers turned over the work to Far*gh*ānī. The caliph heard that because of an error in sloping the canal wouldn't function. He announced that if this information was confirmed he will crucify the brothers near the canal and orders Sanad bin 'Alī as the consultant for this inquiry. Sanad bin Alī, making an agreement with the brothers proclaimed that no error had been made. The error, if any, would be seen in four months when the slope of the water decreased. The astrologers had predicted that the caliph would shortly die. Two months after this event the caliph was assasinated and the brothers were saved from the proclaimed crucification.

e) **Muntaṣır** (861-862): The caliph had seen a nightmare shortly before his death and he wanted Muḥammed bin Mūsā with Ali Yaḥyā to comment on it.

f) **Musta'īn** (862-866): When he was proclaimed as caliph, Moḥammed had prevented the election of the caliph's brother Aḥmad. Aḥmad had surrounded Baghdad and the commander of the city had sent Muḥammed as an envoy to guess the number of the surrounding army. Also, in the same year there was a revolt and talking to the citizens of Baghdad, he acted as an envoy in the agreement involving Musta'īn's abdication. One condition of the abdication agreement was that the caliph had to live in Medina but could visit Mekka freely. But, since their going to Mekka had been prevented, they stayed in Baṣra. The references note the following conversation: Muḥammed says "Baṣra is a source of plague. How could one stay here?". The caliph answered, "Which is a stronger source of plague, the Baṣra or the loss of my caliphate?". It is stated that during this time a canal called the "astrologer's column" between Vāsiṯ and Baṣra was dug with the guidance of the brothers.

Aside from these events no information is given about the Banū Mūsā brothers. It is only known that Muḫammed died during the caliphat of Mutemid in year 873.

The following is known about the lives and personalities of the brothers:

In their youth they lived a simple life. This changed later due relatively to their incomes and their relations with the ruling caliphs. But, in all their activities they stayed and acted close together. For instance, in the election of the caliph Musta'īn, Muḫammed and Aḫmed worked together, and in the canal event the death of all three brothers was proclaimed.

Their relations with other contemporary scholars were generally friendly. They were cordial with Hunayn bin Isḫāq and they had close enough relations with *Th*ābit bin Quarrā to let their works be read by him and asked for his considerations on them. They were exchanging ideas with the famous astronomers of their times. For example, Muḫammed was in continuous contact with the astrologer Abū Ma'*sh*ar and their guardian Yaḥyā bin Abī Manṣūr. In spite of this it can be seen that unpleasant things were written about them because they intrigued against anyone who had priority in their own research subjects. For instance, they tried to keep Sanad bin Alī, who lived in Baghdad and had scientific discussions with Aḫmed, far away from the caliph living in Samarra. On the other hand, Sanad bin Alī, showing his generosity, had saved their lives on the canal affair.

Their hostility against al-Kindī was great. They criticized and ridiculed a work of him on the astrolabs. According to al-Bīrūnī, their quarrel had reached such a state even to turn children's hair grey. Bīrūnī disliked them merely for this reason. Influencing the caliph Mutavakkil, they removed al-Kindī from the palace and seized his rich library. After the canal affair the library was handed back to its owner by Sanad bin Alī.

Scientific Works:

The Banū Mūsā brothers, merely touching philosophical topics, worked on all the branches of the mathematical sciences called "riada". Isḫāq bin Hunayn translated many medical works from Greek for them. Their student and friend *Th*ābit bin Qurrā worked mainly in medical subjects, but the brothers themselves were not been involved in medicine.

According to the catalogues given by Ibn al-Nadīm and Ibn al-Qiftī, the works of the Banū Mūsā brothers are as follows:

1) Book on the steelyard (qarastūn): There is a similar work on the same subject written by their student *Th*ābit bin Qurrā.
2) Kitāb al-Hiyal (the book of ingenious devices): A work of Aḫmed, almost the entire text exists today.
3) Book on the long, curved figures (ellipses): A work of al-Haṣan which is lost.
4) Book on the first movement of spheres: A book written by Muḫammed which is also lost.
4) Book on the first movement of spheres: A book written by Muḫammed which is lost.

5) Book on conic sections: A lost book written by Muḫammed about the eighth book of Apollonius.
6) Book on the "three": A lost book written by Muḫammed, the meaning of which is uncertain.
7) Book of the geometrical shapes, as demonstrated by Galen (Menelaos?): A lost book by Muḫammed.
8) Book of the parts (proportions?): By Muḫammed, also lost.
9) Book in which it is demonstrated by didactic means and by geometrical method that there is no ninth sphere outside the sphere of the fixed stars: A lost book by Aḫmed.
10) Book on the beginning of the world: A lost philosophical work by Muḫammed.
11) Book on the question put to Sanad bin Alī by Aḫmad bin Mūsā: Lost.
12) Book on the nature of speech (kalām, rhetoric): Lost.
13) Book on the questions discussed between Sanad bin Alī and Aḫmed bin Mūsā: Lost.
14) Book on the measurement of the sphere, division of an angle into three equal parts and calculation of the mean proportional between two quantities: The original manuscript and translations into Latin exist today.

Additional to the above given works registered in the catalogues, the following are also said to be the works of the Banū Mūsā brothers:

15) On the sphere.
16) Astronomical tables.
17) On the construction of the astrolabes.
18) Two works on time, edited by *Th*ābit bin Qurrā.
19) About musical automation (the text exists).
20) About war engines.

2. KİTAB AL-HİYAL AND EXİSTİNG MANUSCRIPTS [3, 4, 5, 6, 10, 11, 13, 20]

During the Hellenistic period and the Middle Ages, people were continuously interested in the "ingenious devices"; i.e., the mechanical automata working by the aid of air and water. Many books for instance had been written on the subject of "horror vacui" (horror of vacuum) or the principle of the siphons frequently used in these systems. The construction of vessels pouring out two or more liquids separately, mixed or not, is a subject that put this theory into practice, and has occupied intensely the minds of scientists. In the world of Islam, working on this subject is called "Ilm al alat al ruhaniyat" (the science of pneumatic devices) or "Ilm al ḥiyal" (the science of ingenious devices).

The science of pneumatic devices is defined by Akfani as such: "The science of pneumatic devices is based on the principle of the lack of vacuum and its subject matter is how to construct them. Its aim is to educate the mind with the construction of these systems which are formed by the help of balanced cups, the over-running cups, the siphons and other construction elements".

The works that are known to have been written on the subject during the Hellenistic period are:

1) Ingenious devices by Ctesibius of Alexandra (3 rd century B.C.): Even though this work is lost, the work of Vitrivius called "Architecture" describes some devices.

2) Pneumatics by Philo of Byzantium (probably 3 rd century B.C.): The Arabic translation exists in the Süleymaniye Library-İstanbul (A. S. 3713).
3) Pneumatics by Hero of Alexandria (1 st century A.D.): The original text exists.
4) A book on a waterclock assumed to be written by Archimedes: A text probably composed in Arabic exists.

The works known to have been written on the subject in the world of Islam are;

1) Kitāb al-Ḥiyal by Banū Mūsā,
2) An article by Farabi on the subject of vacuum,
3) Kitāb al-Ḥiyal by al-Jazarī (book written in 1206),
4) A work by Ridwān bin al-Sa'ātī on the subjects of a waterclock in Damascus (book written in 1203).

The main manuscripts of the Kitāb al-Ḥiyal by Banū Mūsā brothers are

1) Vatican manuscript (No. 317); copied by a certain philosopher, al 'Afrīt.
2) Berlin/Gotha manuscript (Ahlward No. 5562 / Pertsch No. 1349); this manuscript in state of two fragments-is dated "Friday, the 4 th of June 1210.
3) Topkapı Sarayı manuscript (A 3474); is the oldest and most reliable copy; unfortunately the beginning and the end are missing.

Although the existing copies have missing parts and are in disorder, it is possible to put together the work by the aid of the known fragments. It is assumed that some 100 different models are discussed in the original work. Among these, only 25 models have practical value. The remaining models mainly formed by ingenious cups, with the purpose of puzzling people who do not know the work, are mostly designed to be used in drinking parties. In the models, a limited number of motifs have been used and by the variation of these, various affects have been reached. It can be accepted that some of the models have never been realised.

CHAPTER II
MOTIFS

In the sense of system engineering, the models in the work "kitab al-Ḥiyal" are formed by the combination of a limited number of motifs. To understand the working principles and to derive the models of these systems, first, the basic motif has to be examined. One observes that certain motifs are frequently reused in different models and others are rarely used or developed to be used only for one determined system [8].

To study the motifs separately, one has to determine the physical principles that each motif is based on. By means of dynamic equations approximate mathematical models are derived, in agreement with the physical principles, specific simplifications and possible assumptions. Thus, the entire model of the system is obtained by combining the individual models of the motifs. The mathematical models are expressed by block diagrams in accordance with the terminology of system engineering. In the block diagrams the linear or linearized functions are expressed through transfer functions. In system engineering, the transfer function of a linear system is defined as the Laplace transformed ratio of the output variable to the input variable. This ratio is formed when all the initial conditions are taken as zero. The transfer function concept is equivalent to the Laplace transformed impulse response of the system.

The unlinearized elements, or elements that effect the system with their nonlinear characteristics, are shown in the models through nonlinear blocks. These nonlinear blocks are drawn double-framed in the models. In these blocks the input-output relation is drawn in cartesian coordinates, the input variable taken on the apsis and the output variable on the ordinate [9, 12].

Aside from the linear and nonlinear blocks, logic and memory elements are also used in the system models. Logic elements are given through conventional symbols. For valves and taps, the symbol of a switch is used. Special symbols are also derived as in the model of the turbine motif. Evaluating different properties it is possible to give different models of a given system. For the realization, the most suitable model is chosen and it is kept unchanged throughout the work as far as possible, although difficulties come up specially in deriving the model of the "balanced valve with two or three positions" (See Motif 6).

The following are the main motifs and their models used in this work.

Motif 1-Siphon

The siphon known in Arabic is ka's al-'adl (cup of equivalence) is based on the principle of joined cups in physics. Although in the models the siphon is realised in two different manners, it does not bring out a difference in the effect. Generally, it is drawn as a pipe covered with a capsule, piercing the bottom of the tank containing it (Figure Ml-a). There are also siphons which are realised as u-type folded pipes piercing the side wall of the siphon containing tank (Figure Ml-b).

When a liquid with the flowrate q_g is poured into the tank containing the siphon, the level h of the liquid in the tank rises. The liquid begins to flow out through the siphon when the level reaches h_s, the upper end of the siphon. When the flowrate of the liquid flowing through the siphon is $q_ç$, and the cross-section A of the tank is assumed to be equal along the height, the following equation can be formulated between the difference of in - and outflow rates $\triangle q = q_g - q_ç$ and the level h:

$$\triangle q(t) = A\frac{dh(t)}{dt}$$

If the Laplace transform of this equation is taken, s being the complex frequency, the transfer functions between the level h and the flowrate difference $\triangle q$ is obtained as

$$\frac{H(s)}{\triangle Q(s)} = \frac{1}{As}$$

where $H(s) = L[h(t)]$ and $\triangle Q(s) = L[\triangle q(t)]$ are the Laplace transforms of the variables.

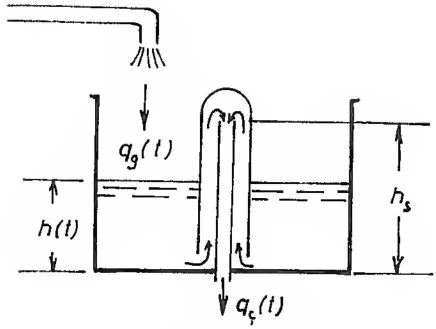


Figure M1-a

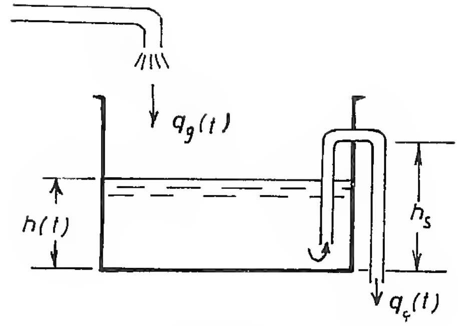


Figure M1-b

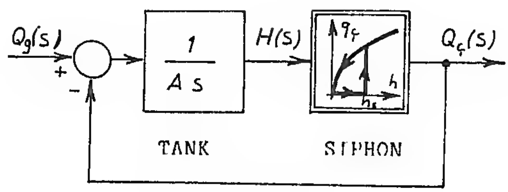


Figure M1-c

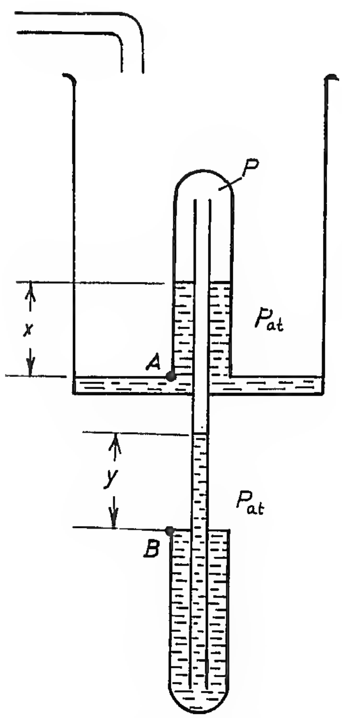


Figure M2-a

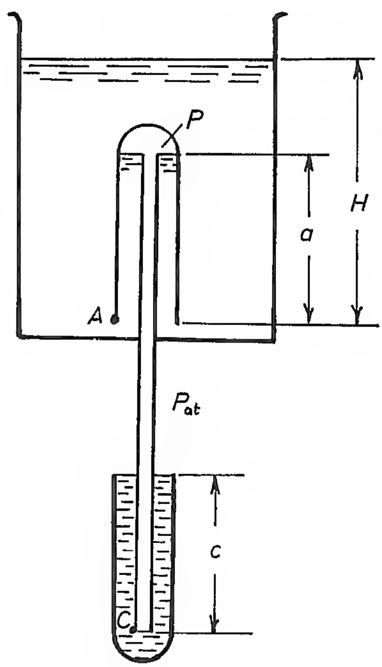


Figure M2-b

When the level of the liquid in the siphon tank reaches the level $\mathbf{h_s}$, the siphon begins to pour out the liquid obeying the free flow law

$$q_ç = a\sqrt{2gh}$$

in which **a** is the cross section of the outpouring pipe and **g** the acceleration of the earth gravitation. Thus, the relation of the level **h** to the outflowrate $\mathbf{q_ç}$ is parabolic:

$$h = \frac{g_ç^2}{2ga^2} = k.g_ç^2\,, \qquad k = \frac{1}{2ga^2} = \text{constant}$$

The outflow of the liquid through the siphon continues till the liquid level in the tank is annulled. After the out-flow has stopped re-emptying depends on the liquid reaching level $\mathbf{h_s}$ in the siphon tank. This is the reason for which the siphon is shown in the block diagram by a non-linear block (Figure Ml-c). The tank and the siphon together form a feedback system, in which $\mathbf{Q_g}$ and $\mathbf{Q_s}$ are the in - and output variables, and the level **H** an intermediary variable.

Motif 2-The Double Siphon

The double siphon motif is formed by two concentric siphons (Figure M-2a). This motif works first like a simple siphon, but since after an interruption of the inpoured liquid the outflow through the double siphon is blocked, the motif acts generally like a switch. The level of the liquid poured into the double siphon tank can be raised up to the upper point of the upper siphon. At this state the upper siphon starts to conduct the liquid in the concentric second siphon. Thus, the liquid overflowing from the upper edge of the second siphon pours into a lower tank beneath it. The flowing of liquid continues as long as the flowrate of the inpoured liquid is sufficient to keep it outflowing.

If the inpouring of the liquid is interrupted for a time, the level of the liquid in the upper tank sinks till the end **A** and air enters into the upper siphon (see Figure M2-a). At this moment some of the liquid in the upper siphon flows back into the tank and a new equilibrium state is formed as seen in Figure M2-a. $\mathbf{P_{at}}$ being the atmospheric pressure, **P** the pressure in the siphon, x and y the liquid columns in the siphons, ϱ the specific mass of the liquid and g the acceleration of the earth gravitation the equilibrium of the pressures at the points A and B are given by

$$P_{at} = \varrho g x + P = \varrho g y + P$$

or

$$x = y .$$

When liquid is repoured into the tank containing the siphon, the air inside the upper siphon is pushed back by the liquid to the lower siphon. After a liquid column of height y + c is pushed out from the lower siphon, the air starts to bubble-out from the point C as seen in the Figure M2-b. The height H, that the liquid has to reach in the tank so that a continiuous flow through the siphons can restart, is found by the equilibrium of the pressures at the points A and C. The pressure equilibrium at A

$$P_{at} = \varrho g H = P + \varrho g a$$

and C

$$P = P_{at} + \varrho g c$$

joined gives

$$H = a + c.$$

Thus, in order to prevent a second flow through the double siphon, the height of the siphon tank has to be smaller than a+c.

The double siphon motif, that physical principles are examined above takes on the following function in the systems: when the flowing of the liquid, that flows with a constant flowrate through a determined track, is interrupted for a time, the double siphon prevents the liquid to flowing the same track when the flowing of the liquid restarts. This motif solves the problem of storing different liquids in different tanks

t	x_1	x_2	y
t_1	1	0	1
t_2	0	0	1
t_3	0	1	1
t_4	0	0	0

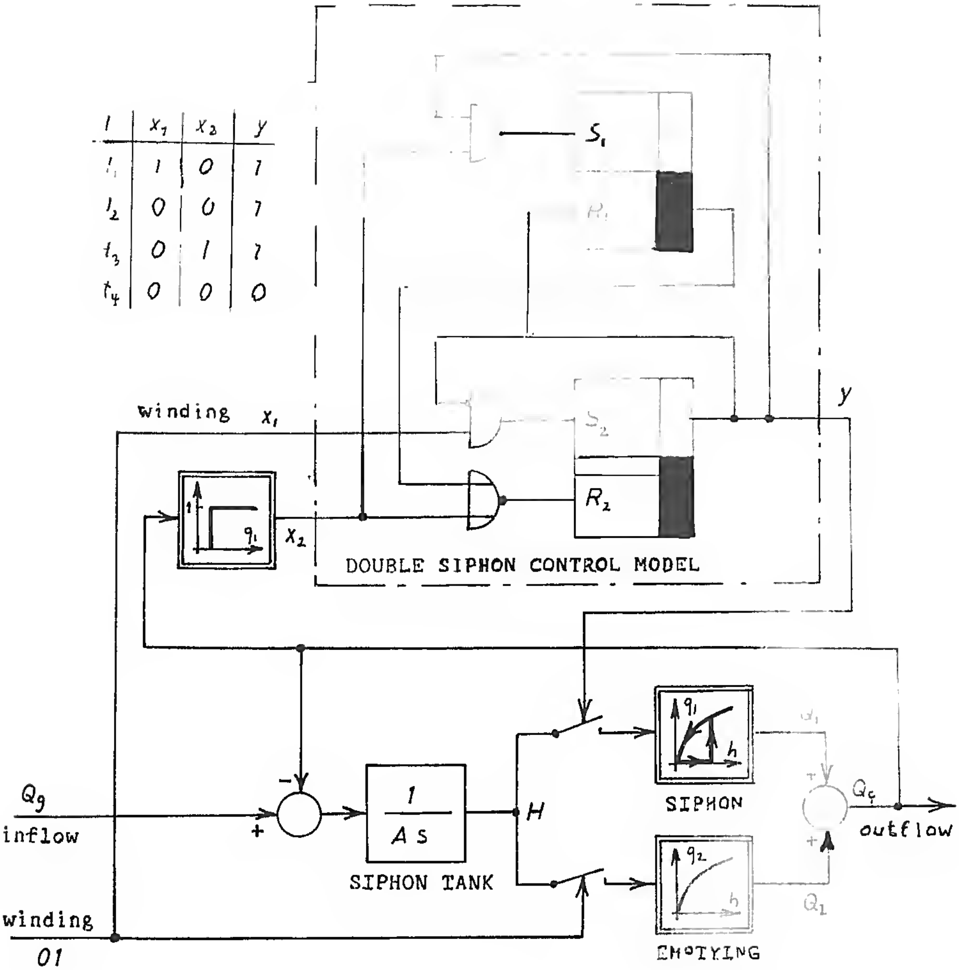


Figure M2-c

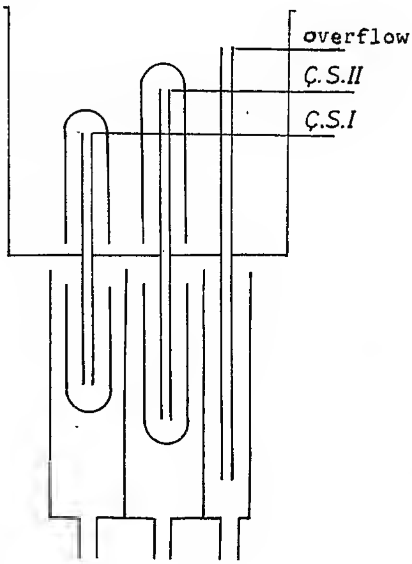


Figure M2-d

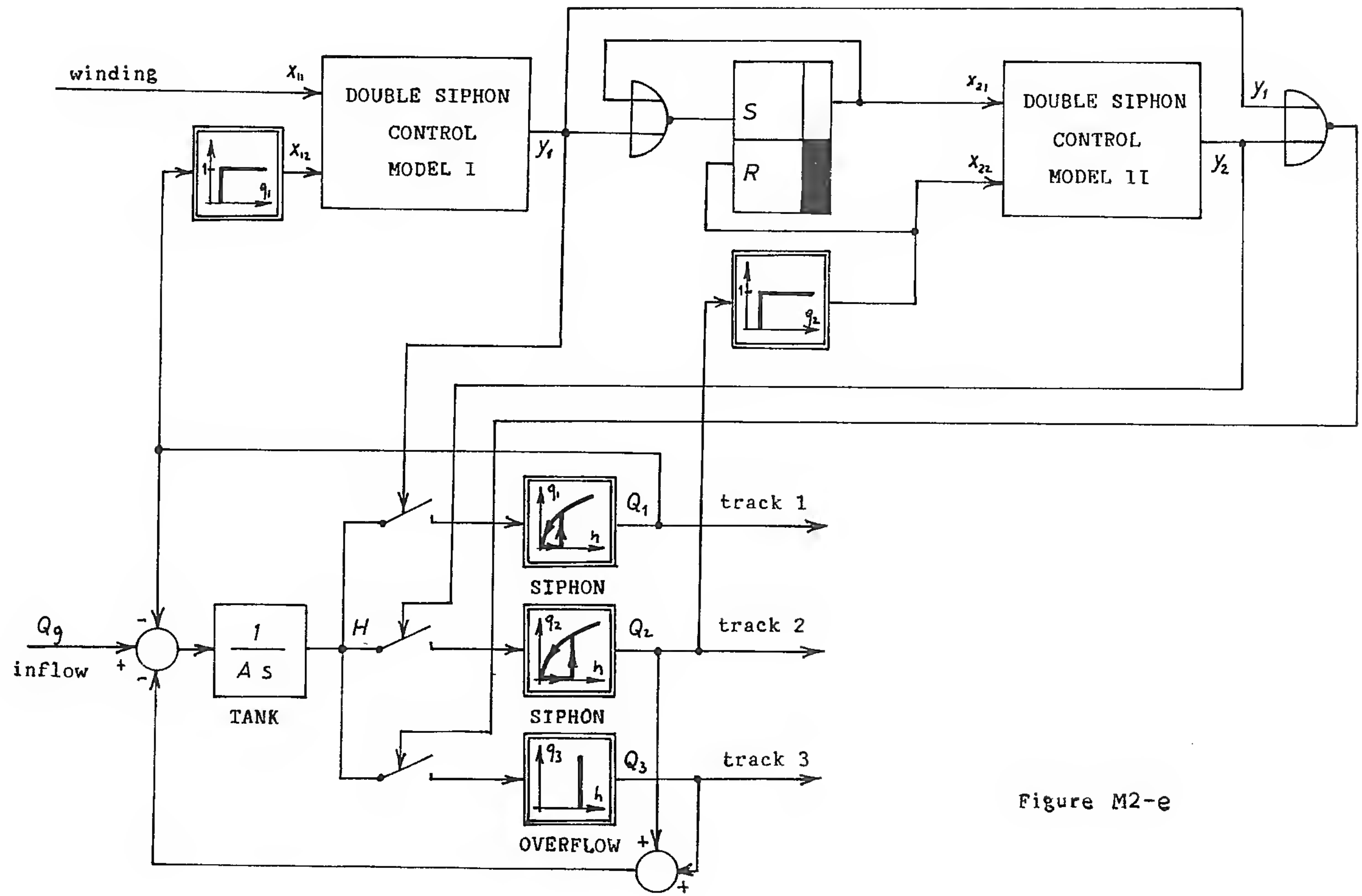

winding
DOUBLE SIPHON
CONTROL
MODEL I
DOUBLE SIPHON
CONTROL
MODEL II
S
R
x_{11}
x_{12}
y_1
x_{21}
x_{22}
y_2
Q_g
inflow
1
A s
TANK
H
SIPHON
SIPHON
OVERFLOW
Q_1
Q_2
Q_3
track 1
track 2
track 3

Figure M2-e

in the models.

If one wants to derive a model of the double siphon this has to be done as a siphon model and a control logic model separately (Figure M2-e). The model of the siphon is formed by a linear tank and a nonlinear siphon model block like Motif 1, while the control logic is composed of logic and memory elements. When in the control logic $\mathbf{x}_1$ means the winding on (or the emptying) of the siphons, $\mathbf{x}_2$ the pouring of the liquid in the siphon tank, and $\mathbf{y}$ the flowing of the liquid through the double siphon, then the truth table given in Figure M2-c is formulated. The variation of the states as a function of time is shown in the **t**-column of the truth table. The logic table is realised by the aid of two S-R memory elements. When the system is wound the output signal $\mathbf{y}$ becomes **1** and stays unchanged till the pouring is interrupted or $\mathbf{x}_2$ becomes zero. After one interruption of the inpouring, flowing through the siphon is blocked for all $\mathbf{x}_2 = \mathbf{1}$ signs unless the system is rewound or the double siphon is emptied. The connection between the basic siphon model and the control model is formed by a switch settled between the tank and the siphon block. When it is desired to have various liquids directed towards various tanks, double siphons with different lengths are put side by side in a tank (Figure M2-d). The last liquid is usually seperated by an overflow pipe. The control model for a ''two double siphon and an overflow pipe'' motif which is frequently used in the systems is seen in Figure M2-c. In this situation, in order to wind and to trigger the circuit on time, additional S-R memory elements are put between the double siphon control models.

In model 48, a double siphon and a overflow pipe with an automatic rewinding is given (Figure 48 a and b). To obtain this effect, the lower siphon of the double siphon is connected to another siphon, so that both siphons are emptied by the liquid flowing through the overflow pipe and the system rewinds automatically to its first condition.

Motif 3-Control by Flowrate

In the systems the problem of collecting different liquids in different tanks may be realised by the ''control by flowrate'' motif as well as by the double siphon motif. The separation is done by regulating the flowrate of the inflowing liquid by the pouring person. If the liquid is poured gently into the funnel like partition, it runs into one tank and if it is poured forcefully it runs into another tank (Figure M3-a). Since the flowrate in the systems is usually an input variable, this motif as seen in Figure M3-b effects like a switch in the block diagrams. In this model intermediate conditions where some liquid will follow the track 1 and some the track 2 is not foreseen.

There are other flowrate control models apart from the type in which a clear separation of the liquids is given, for example in system 60 this motif is constructed in the form of a pipe (Figure M3-c). The liquid flowing through the pipe flows out according to the flowrate from the outlets 1, 2 or 3. If the proportionality coefficients for the outlet flowrates are so selected that the condition $K_1 + K_2 + K_3 = 1$ is ensured for all inpouring flowrates Q_g (see Figure M3-d), one obtains the block diagram seen in Figure M3-e. In this model, the outpouring proportionality to the inpouring flowrate, is realised by multiplying function blocks.

Motif 4-Floated Valve

A floated valve is formed by a tank containing a float which controls a valve with a bar fixed to it. There are two different models of this motif: one is the opening-type and the other is the closing-type floated valve model (Figure M4-a and b). The valve can control the in and out flow rate over the float containing tank (self control) as it can control the flowrate in an other part of the system (external control). The block diagrams of various applications are seen in Figures M4-c, d, e and f.

Motif 5-Valve Controlled by a Floated Tank

A valve controlled by a floated tank is a motif developed from the floated valve motif given above. The aim is to prevent the float rising and the valve from changing its position, all the while liquid is being poured into the float containing tank. For this reason, the inpoured liquid runs first into the tank, which is over the float (Figure M5-a). When this tank is filled, the liquid overflows over the upper edge and runs into the tank containing the float. As long as the tank on the float is full

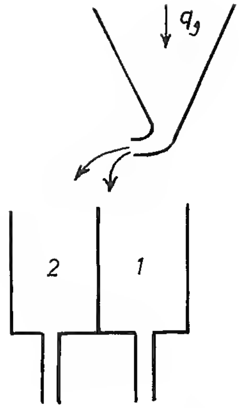


Figure M3-a

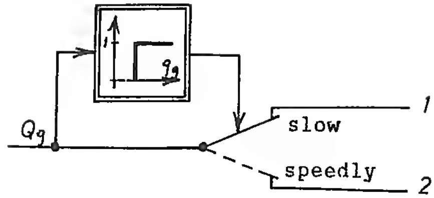


Figure M3-b

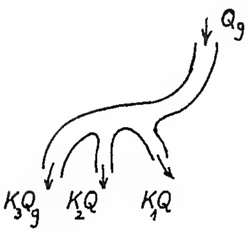


Figure M3-c

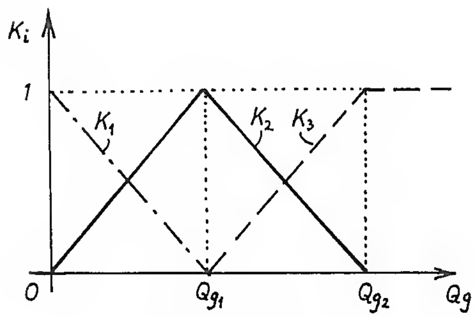


Figure M3-d

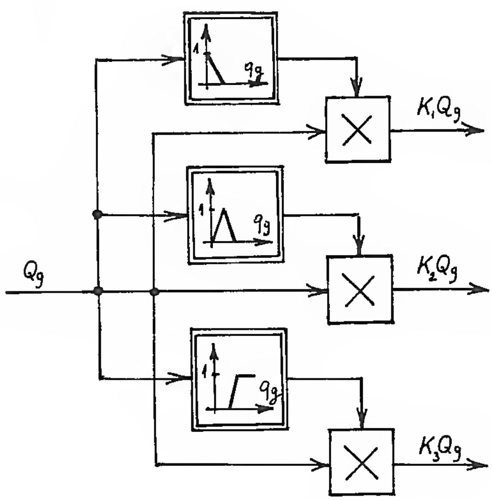


Figure M3-e

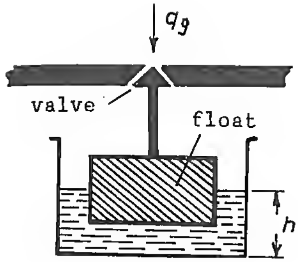


Figure M4-a

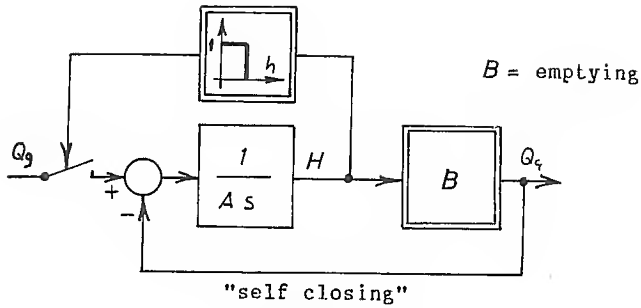


Figure M4-c

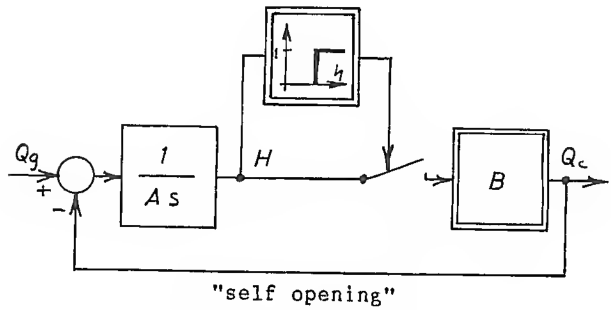


Figure M4-d

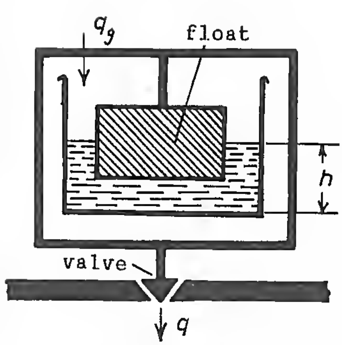


Figure M4-b

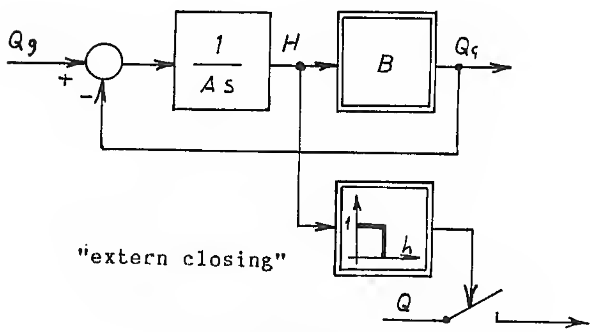


Figure M4-e

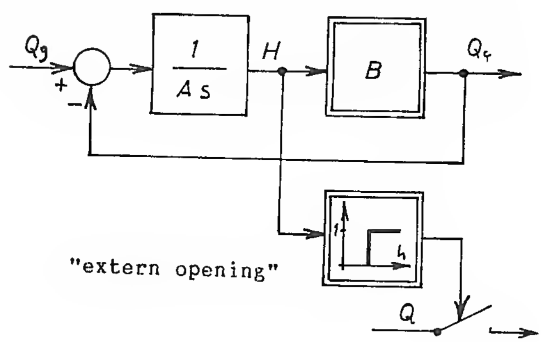


Figure M4-f

of liquid the float can not rise and the valve cannot change its position. When the filling procedure ends or is interrupted for a while the liquid in the float tank runs down either through a hole at the bottom of the tank (type A) or through a siphon (type B). The valve changes position when the float begins to rise. A closing-type valve controlled by a floated tank is seen in Figure M5-a and an A-type floated tank model is given in Figure M5-b. In the derived model the **x** variable is taken as an output variable, because the valve controlled by this variable, for which the truth table is given, has different forms in the systems. Since, the emptying of the float tank can be realised in the form of free flow, overflow, or the use of a siphon etc., the emptying block is kept outside of the generalized model.

Motif 6-Balanced Valve with Two or Three Positions

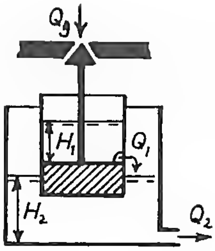
The balanced valve with two or three positions is generally used in place of the valve controlled by a floated tank. In the simple balanced valve with two positions which is given in Figure M6-a, the poured liquid runs first into the tank that is on one of the balance arms. When the tank fills up, with the changing of the balance equilibrium the valve position on the other balance arm changes. To return to the beginning state, the tank on the arm has to be emptied. The emptying of the tank can be realised in the form of free flow (Model 57), the use of a siphon (Model 73) or in the form of ''successive steps'' (Model 50). When the emptying is in the form of ''successive steps'', it is intended to keep the balance in a continuous oscilation. In some applications, the liquid is transferred from the tank by a pipe running along the arm of the balance to another cup which is placed on the other arm of the scale, so that the oscilation period can be regulated (Model 56) and if desired the balance system can be locked after being used once. In Figure M6-b a balanced valve, with two positions that is locked after being used once is given. When the inflow is interrupted the liquid in the tank over the right arm of the balance empties flowing into the tank on the left arm through a pipe along the balance arm. The equilibrium of the balance changes, the balance arm inclines to left and the valve closes. Thus, unless the tank on the left arm of the balance is not emptied, the system stays locked. In Figure M6-c, the block diagram of a simple balanced valve with two positions (see Figure M6-a) is given. Here, the balanced valve is used to obtain a system, that does not pour out liquid, as long as a liquid is poured with a flowrate Q_g into the system.

The three-positioned balance is constructed in some systems, as in Figure M6-d, like a balance with arms in form of two cups. Bars tied on the edge of the cups turn on or off the corresponding valves. When the cups are empty or full with equal quantity of liquid the balance stays in the middle position. According to the difference in the level of the liquid in the cups, the balance tilts to the right or to left side, turning the valves to the on or off position. In the block diagram (Figure 76-e), the balance is modelled by nonlinear blocks. First, depending on the difference $\triangle h$ of the level in the cups, the states 1, 0 and -1 are detected. The hysteresis in the characteristic is due to the rubbing of the bearing when the balance is leaned. The turning on and off of the valves is modelled by a second nonlinear block.

In the models the floated balance motif is also used (see Model 57). The position of a balance like cup (Figure M6-f) is determined by floats placed under the balance cup. The liquid that is poured into the balance cup, runs through the outflow pipe into the right tank 1 or left tank 2 according to the position of the balance. The level of the liquid in these cups determine the position of the balance. In the block diagram given in Figure M6-g the balance with two positions is modelled by an S-R memory element. In this model the state corresponding to the fullness of both of the cups (i.e. uncertainty) has not been considered. In this application when one of the outlets is closed by hand, the level of the liquid in the corresponding cup rises and the balance changes position.

Motif 7-Air Obstacle and Air Control

The blocking of the air entrance and exit from the tanks is another way to effect the flow of the liquids. As seen in Model 12 (Figure M7-a) the liquid poured into the upper partition of the pitcher passes an air obstacle before running into the pitcher. The air obstacle is formed by a tube and a concentric pipe extending upwards out from this tube. The liquid, that remains at the bottom of the tube, which does not prevent the flow of the liquid, forms an air obstacle between the upper partition



H_1	H_2	X
b	b	1
d	b	1
d	d	1
b	d	0

b= tank empty
d= tank full

Figure M5-a

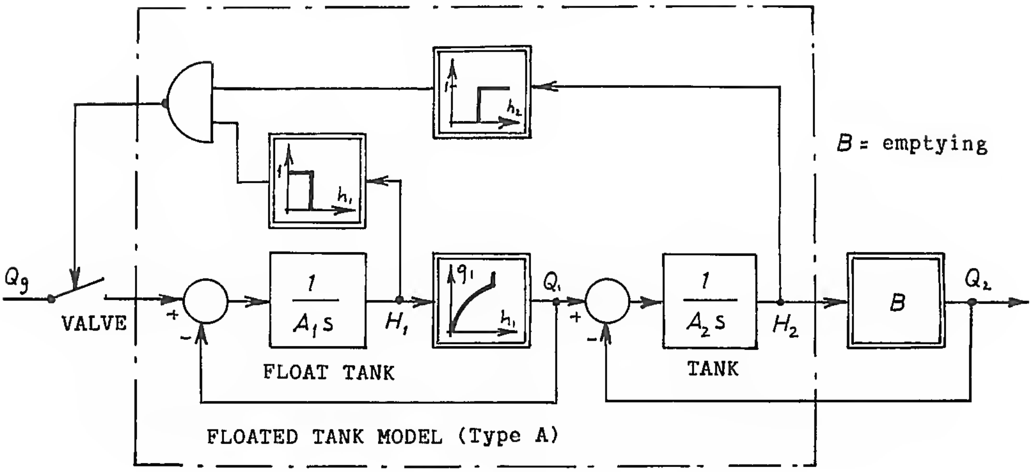


Figure M5-b

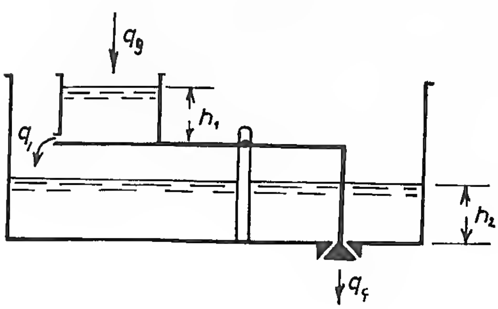


Figure M6-a

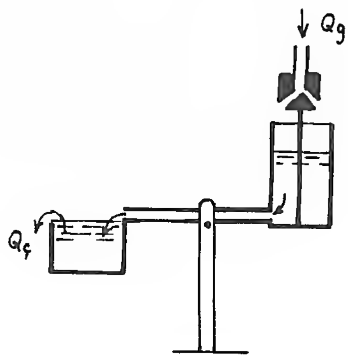


Figure M6-b

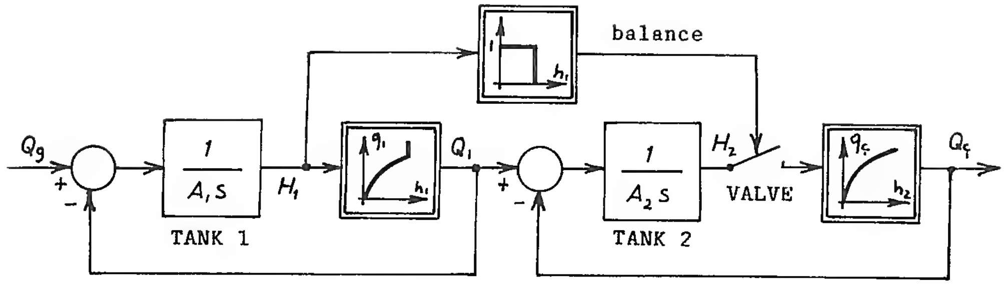


Figure M6-c

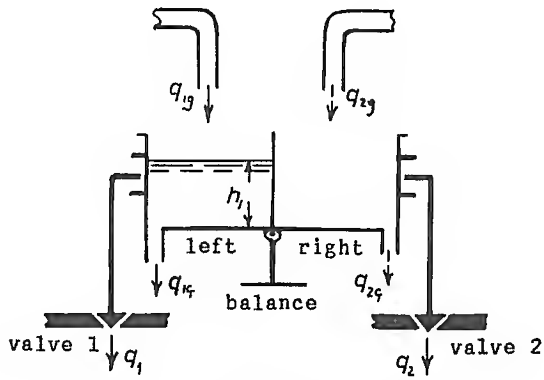


Figure M6-d.

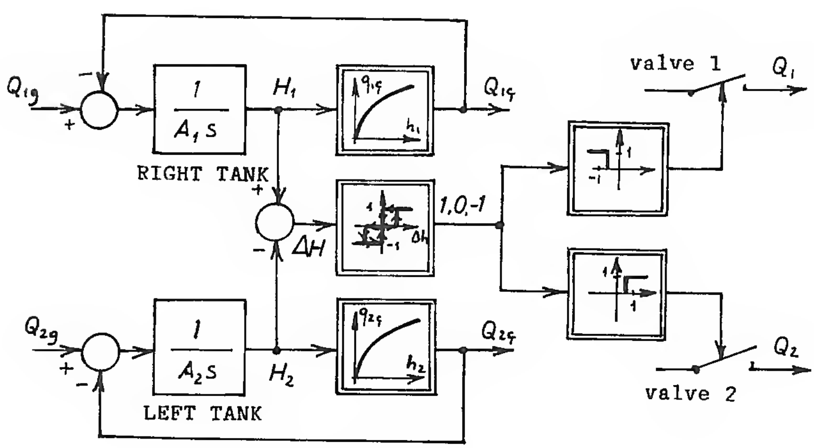


Figure M6-e

and inside of the pitcher. When tilted, if the user also closes the secret air hole existing at the handle, the liquid does not pour out even though the pitcher is full. The block diagram is given in Figure M7-b.

Using this motif it is possible to lead different liquids in different tanks. As seen in Figure M7-c, to achieve this effect a second pipe longer than the first one is placed in the air obstacle tube. After the liquid that has to flow into the first tank is poured, the air exit of this tank closes. When the filling restarts the liquid flows into the second tank through another overflow pipe that is on a higher level (see Model 55).

Motif 8-Pressure Equilibrium

As seen in Figure M8-a the pressure equilibrium motif is formed by two air connected tanks (see Models 54 and 55). The liquid poured into the first tank through an air obstacle with the flowrate q_g forms an air pressure difference Δp in the tanks. This pressure difference causes the outflow of some liquid with the flowrate $q_ç$. If the level of the liquid in the first tank is h_1 and the cross section of the first tank A_1, ϱ being the specific mass of the liquid and g the acceleration of the earth gravitation following equations can be written

$$q_g = A_1 \frac{dh_1}{dt}$$

for the infowrate and

$$P_1 = \varrho g h_1$$

for the pressure. If one assumes that the outflow rate $q_ç$ is proportional to the pressure difference $\Delta p = p_1 - p_1$ with the equations $q_ç = K_1 \Delta p$, $p_2 = \varrho g h_2$ and $q_ç = A_2 dh_2/dt$ the block diagram in Figure M8-b is obtained. When the block diagram is simplified with the abbreviations

$$\tau = \frac{A_2}{\varrho g K_1} \quad \text{and,} \quad K = \frac{A_2}{A_1}$$

the transfer function

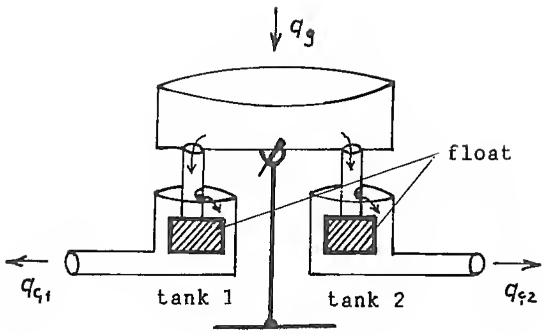


Figure M6–f

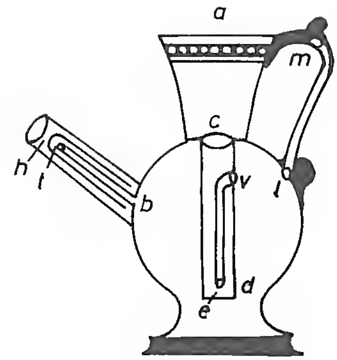


Figure M7–a

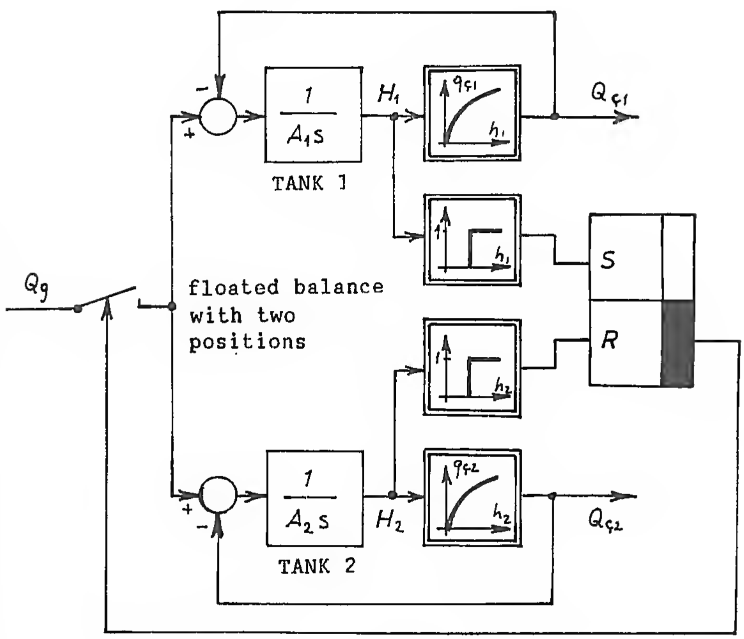


Figure M6–g

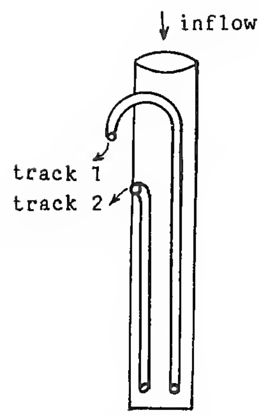


Figure M7–c

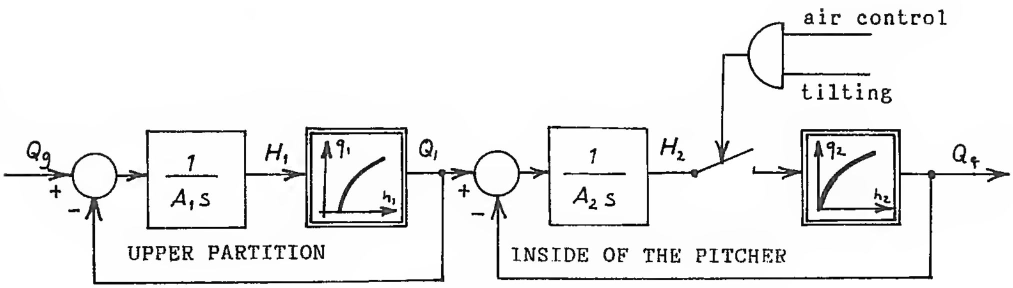


Figure M7–b

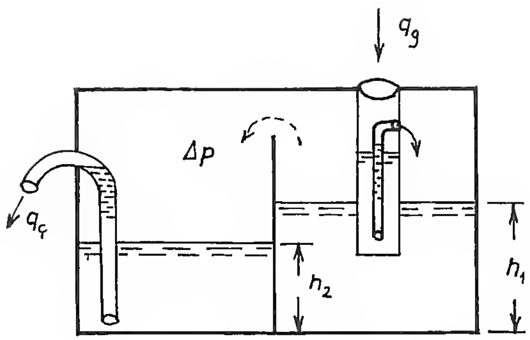


Figure M8-a

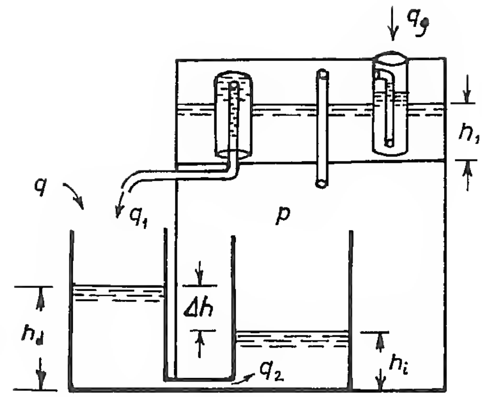


Figure M8-c

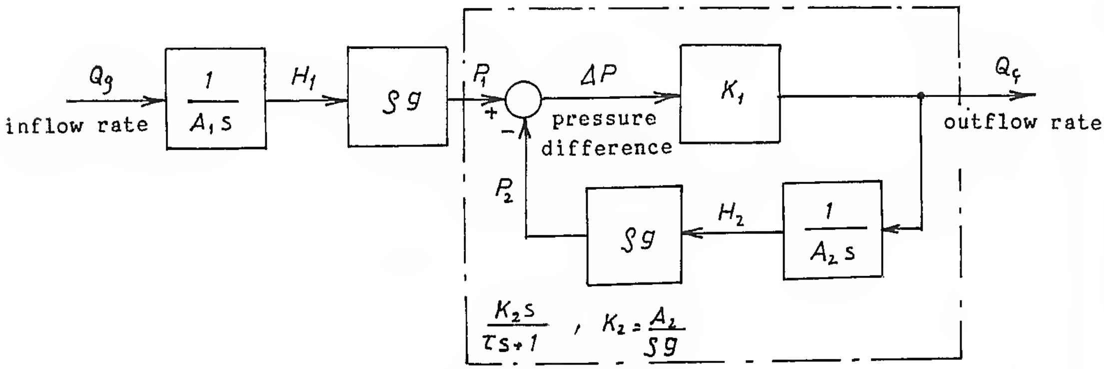


Figure M8-b

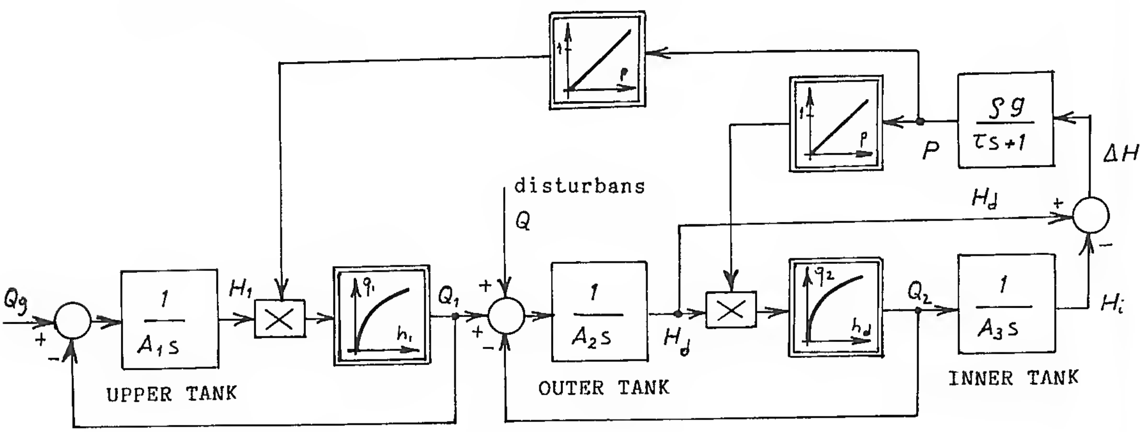


Figure M8-d

$$\frac{Q_ç(s)}{Q_g(s)} = \frac{K}{\tau s+1}$$

is obtained.

Another application of the air pressure equilibrium principle is seen in Figure M8-c (see Model 86). There, the air connected tanks are placed one over the other. The lower tank is in the form of connecting cups so that one of the cups opens to outside. If the liquids in the connecting cups have different levels, h_d being the level of the liquid in the outside cup and h_i the level of the liquid in the inside cup, a pressure proportional to the liquid level difference $\Delta h = h_d - h_i$ is formed. When the tightening of the air is also taken in consideration the pressure variation

$$P(s) = \frac{\varrho g \Delta H(s)}{\tau s+1}$$

can be accepted to be of the first order. The increase of the pressure causes a certain quantity of liquid to pour from the upper tank into the outer cup and some liquid from the outer connected cup to flow into the inner one. These procedures are shown in the block diagram given in Figure M8-d as pressure feedbacks over multiplying elements. In the simplified model, the level difference Δh formed by the disturbance q forms a pressure which causes some liquid to pour from the upper tank into the lower cup at the outside, actually decreasing the air pressure in the tanks, causing the liquid in the outer connected cup to flow into the inner one. The real dynamic equilibrium of the system is very complicated.

Motif 9-Control Valve

The control valve which is used as a control element in the models makes it possible to control the flowrate of a liquid depending on the level of a liquid in a tank (Figure M9-a). The arm tied in the centre of the valve in the form of a crank shaft is turned by a bar fixed to a float. Thus, the flowrate of the valve is determined through a function formed by the float position h_2, the level h_1 of the liquid in the tank over the valve and the valve characteristic. In the block diagram, the effect of the level h_2 is stated by a nonlinear valve characteristic and a multiplying element (Figure M9-b). The effectiveness of the motif changes depending on the valve characteristic. In Model 87 a two positioned control valve shown in Figure M9-c is used. A bar fixed to the centre of the valve stretches like the arms of a balance. On one of the arms hangs a cup and a counterweight is tied to the other end. As long as the cup is empty the valve is turned to right and is closed. When the level h_2 of the liquid, which is poured into the cup with the flowrate q_{g_2}, rises over a certain limit the equilibrium of the balance changes and the valve turning left opens. If the pouring into the cup is interrupted and the liquid in the cup empties with the flowrate $q_{ç_2}$ through the hole on the bottom of the cup, when the liquid in the cup decrease to a certain level, the balance returns to its first position. The block diagram of the system is seen in Figure M9-d. The histerisis in the changing of the balance equilibrium is due to the bearing friction.

Motif 10-Buds of Jetting Fountains

In seven jetting fountain models, which take place between models 88 and 94, the buds of jets are used and applied like a motif. The bud of the jets are separated in two parts by a middle partition. The lower partition is connected to the pipe that carries the water. To jet the water in various forms the upper partition is differently formed (Figure M10 -a, -b and -c). The most applied jettings are in forms of lily, shield and spear.

Various models are improvised in order to jet the water from the same bud in the form of a lily or shield and alternatively in the form of a spear. The spear-like jetting is obtained by a thin pipe that extends from the upper partition of the bud towards the tip (Figure M10-c). The lily and shield-like jettings are realised by little pipes that are inclined and attached around a funnel like part. The water that flows through these pipes from the lower partition into the upper partition is tossed out by centrifugal force in shape of a lily or a shield following the upper shape of the bud. As seen in Figure M10-a, the lily-like bud is in the form of a tulip. The spear-like bud is closed on the top so that the jetted water is tossed back in the form of an umbrella (see Figure M10-b).

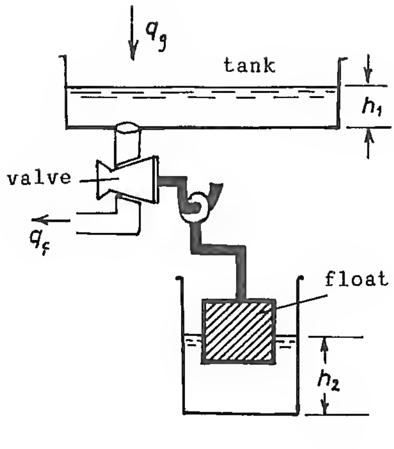


Figure M9-a

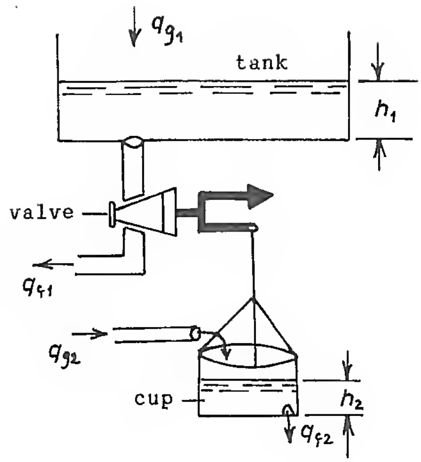


Figure M9-c

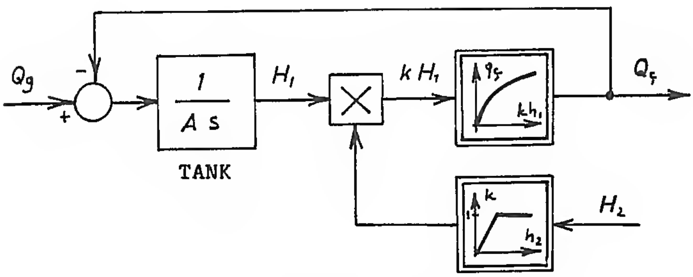


Figure M9-b

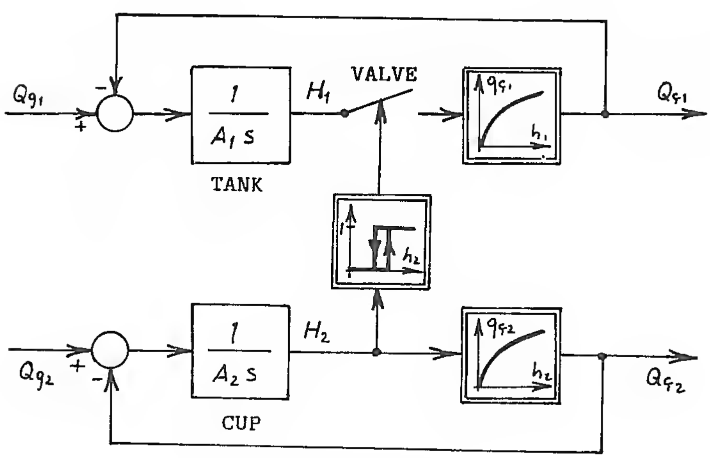


Figure M9-d

In models 92 and 93 a turbine and a water direction regulating mechanism is also placed inside the bud.

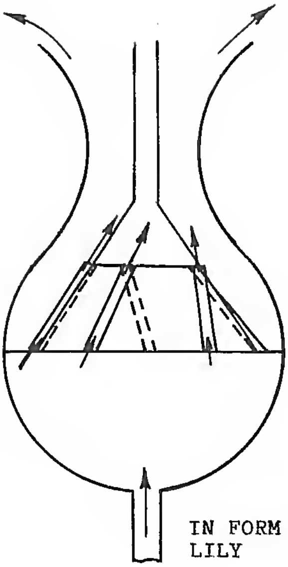
In the block diagrams the form of jetting is written over the tracks that the water can follow, since the shape of jetting is determined by different pipes and partitions the water is directed to.

Motif 11-Turbine

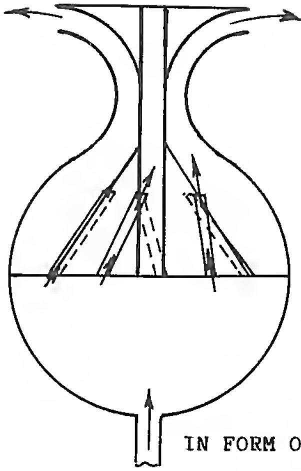
Turbines are generally used in fountain models in order to jet out water in different shapes. It is stated that turbines are turned by wind or water power, but in the models, only the water power applications are given. It is intended to jet out the water, driven with the flowrate q_g through a channel, from different pipes in different forms. For this, the water is first poured on to the paddles of a turbine which is fit to a perpendicular axle (Figure 11-a). The water that turns the paddles, flows into a tank which is on the same axle. While the tank is turning along with the axle, the water runs through a hole alternately in the right and left tanks placed underneath. The water flows from these tanks into different jetting points by means of pipes. The distribution system being in a central place, the jetting of the water is due to the high level of the tanks. For the cases, where the water is conducted to the jetting points under pressure, an interesting system shown in Figure 11-b is used. The liquid from the pipe that ends at the body or the bud of the jetting fountain runs through small pipes and hits the paddles of a turbine. The turning axle of the turbine rotates an endless screw. A gear with a hollow axle which is turned by an endless screw passes the liquid alternately in different pipes (see Figure 92-b). The block diagram of both aplications can be seen in Figure 11-c. There, the turbine motif is symbolised by a circular switch connecting the liquid flowing with the flowrate q_g to different pipes. It is accepted that the angular velocity ω of the switch center is linearly proportional to the flowrate q_g. The proportionality coefficient is given as $K = \omega / Q_g$.

Motif 12-Tap

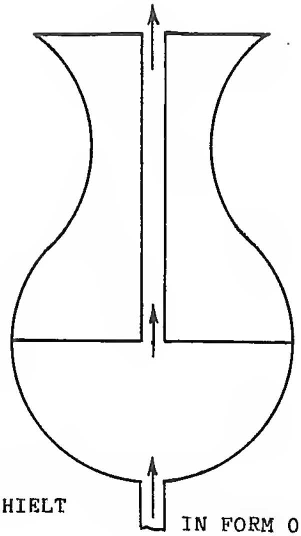
The models are generally in forms of highly ornamented aesthetic cups. The handle of the output taps are often in forms of flowers or animals according to the outer ornamental of the cups (see Figure 12-a, 12-d



IN FORM OF
LILY



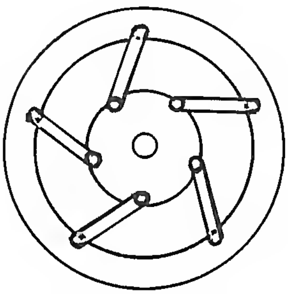
IN FORM OF SHIELT



IN FORM OF SPEAR

Figure M10-b

Figure M10-c



TOP VIEW

Figure M10-a

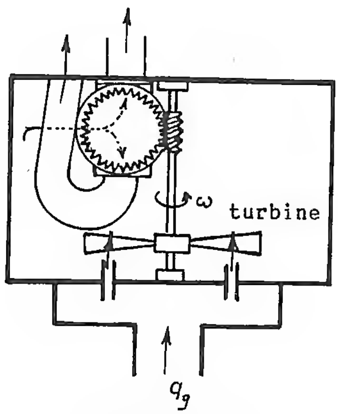


Figure M11-b

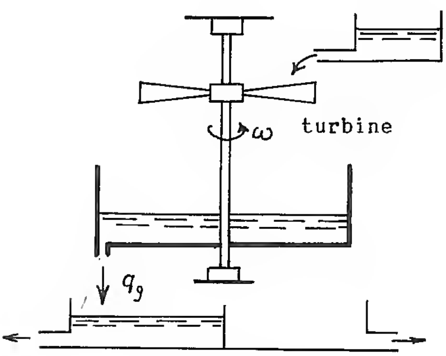


Figure M11-a

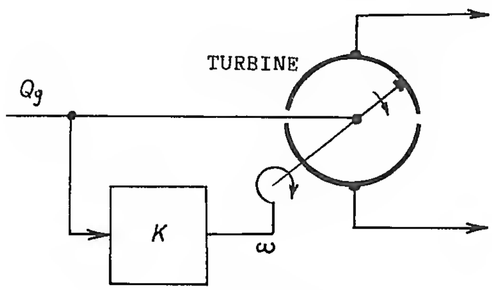


Figure M11-c

and 12-f). These kinds of taps are the same as the ones that are used on earth pitchers or water jars in our times. A vertical tap center is put on the outflow pipe of these cups. The conic tap center which can be turned by an ornamented handle, works smoothly in its bearing and does not leak out the containing liquid. If a hole going through the tap centre is turned on by the handle so that it is in front of the pipe, the liquid begins to flow out from the tap (Figure 12-b). In the block diagrams as seen in Figure 12-c, the taps are shown by switches. When the tap is turned on (open = 1) it is assumed that the level **h** of the liquid in the tank is connected to the output block. The output block which symbolises the function between the flowrate $q_ç$ and the liquid level **h** is generally given by a free flow characteristic. Sometimes the outflow of various liquids are controlled by a tap as seen in Figure 12-d. Then, the outflow of the liquids mixed or separated, is controlled by holes which are in different levels on the tap centre. The ways which are connected by the position of the tap centre is given by a circular switch shown in Figure 12-e.

In Model 21, a chain connected to the tap centre determines the position of a valve (see Figure 12-f). Here, the tap and the valve realise opposite functions: when the tap closes, the valve opens and when the tap opens tha valve closes. In Model 22, the same problem is more elegantly solved by applying an empty tap centre which refills the tank each time the tap is closed (see Figure 22-b).

Motif 13-The Position Changing

In some systems the desired effect is formed by changing the position of the model. For example, as in Figure M13-a, it is possible to canalise the inpoured liquid to different tanks by a movable funnel. For this, one has to incline the system to right, to left or to take it in its normal position. This operation is modelled in the block diagrams, as in Figure M13-b, by a three positional switch.

The position changing is especially effective when liquids are outpoured from vessels. For example, in Figure M13-c the model of a trick vessel is given. Each time it is tilted it pours out a predetermined quantity of liquid. As seen in Figure M13-d this and similar cases are shown

Figure M12-a

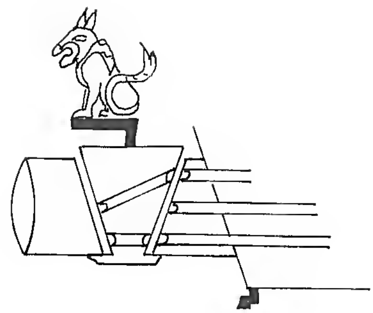


Figure M12-d

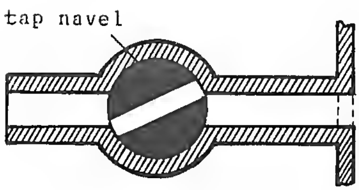


Figure M12-b

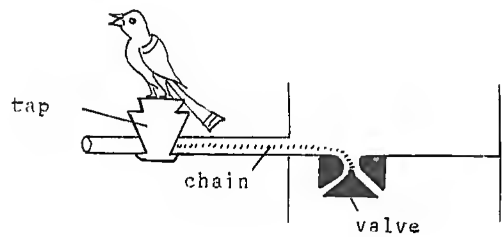


Figure M12-f

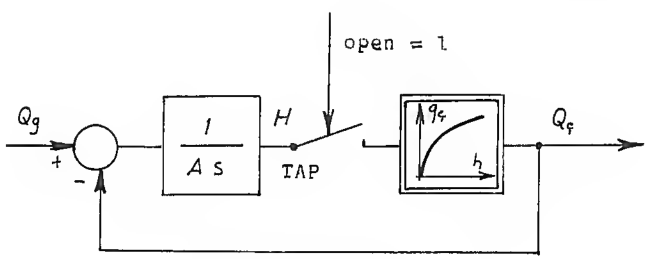


Figure M12 c

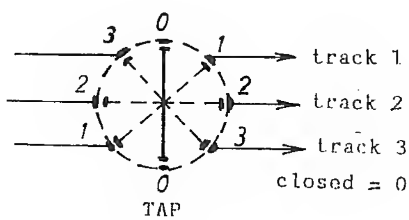


Figure M12-e

by switches in block diagrams. When the vessel is tilted the liquid quantity which is limited by the height **h** of the lower tank, flows out obeying the free flow law. When the pitcher is put to its normal position the liquid in the upper tank fillis again the lower tank.

Motif 14-Directed Valve

The directed valve used in the models are valves which are effected by an auxiliary variable. They let a liquid or air pass only in one direction. The embedded valve seen in Figure M14-a is applied with an air control motif. When the vessel is in its normal position, the valve closes the hole by its own weight and prevents the air from entering. When the vessel is tilted the hole opens since the valve moves into its embedding. The chained valve seen in Figure M14-b works with the same principle. Only, as it is desired the valve opens in its normal position and closes when it is tilted; the center of the valve is hung from a chain. The necessary closing pressure is obtained by a weight fixed on the chain. If it is foreseen to pour liquid through a chained valve, a funnel is placed on the top to collect the poured liquid. In some applications directed valves which open only to one direction, due to obstacles placed on their lid backs, are used (Figure M14-c). The liquid or air can flow by pressure difference only in one direction, but when the sign of the pressure changes the flow to the other direction is not let since the valve lid cannot open. In the block diagrams, the directed valves are symbolised like other types of valves by switches (Figure M14-d). The quantity that effects the opening or closing of the valve is written on the control input.

Motif 15-Gearing

The most important machine element, the gearing, is relatively seldom used in this work. We meet it three times in relation with the turbine motif in form of a infinite screw (Figure M15-a) and two times in a oil-lamp as a wick replacement mechanism (Figure M15-b).

Result:

In the turbine motif, it influences the proportionality coefficient between

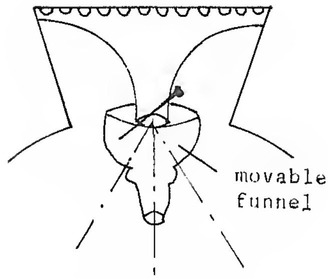


Figure M13-a

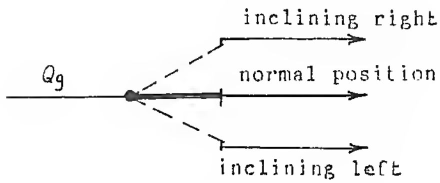


Figure M13-b

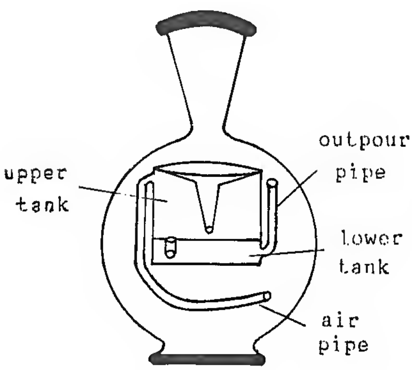


Figure M13-c

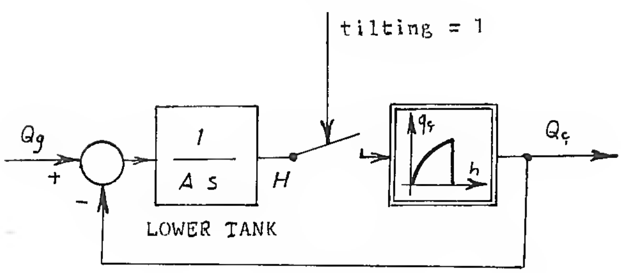


Figure M13-d

the flowrate and the angular velocity. As seen in Figure M15-c, it forms the coefficient factor **K** between the oil level **h** and the amount of replacement **x** in the wick replacement mechanism.

The question, how the fifteen motifs studied in detail and modelled so far are used in the systems, can be answered in the table given below. The numbers in the table show how many times a certain motif is used in each model. As seen from the table the minimum and maximum number of motifs used in a system varies between one and nine (as in system 71). For the models 98 and 100 motifs are not given, that is due to the fact that the principles used in these are not applied in other systems in the work, so extra motifs and models are not formulated.

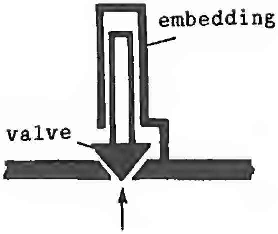


Figure M14-a

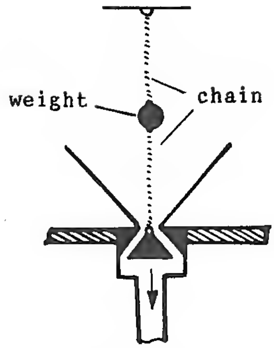


Figure M14-b

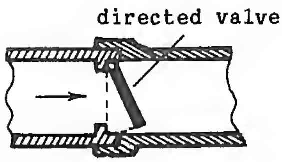


Figure M14-c

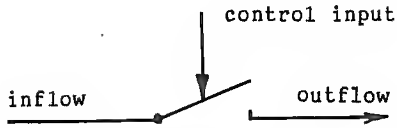


Figure M14-d

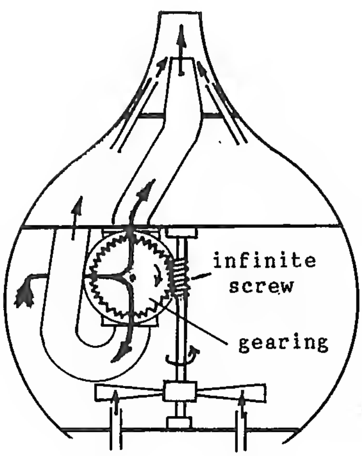


Figure M15-a

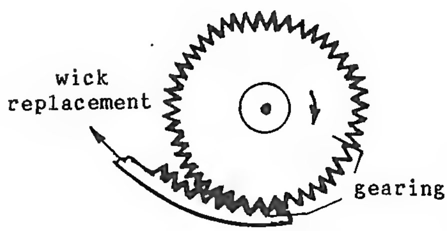


Figure M15-b

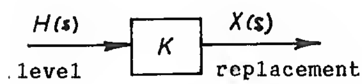


Figure M15-c

MODEL	MOTIF 1	2	3	4	5	6	7	8	9	10	12	13	14	15
1	1													
2	1											1		
3		1										1		
4				1										
5	1			1										
6				2										
7	2			2			1							
8	1				1							1		
9	2				2							1		
10						1						1		
11		2										1		
12							1					1		
13		1					2					1		
14		1					1					1		
15		1		1			1					1	1	
16	1			1										
17	1			1							1			
18	1			1	1						1			
19	2										1			
20		2									1			
21											1			
22											1			
23							1					1		
24							1				1	1		
25							1							
26			1											
27			1											
28								1						
29								1				1		
30							1							
31												1		
32	1			1										
33			1									1		
34												1		
35												1		

MODEL	MOTIF 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
36													1		
37			1										1		
38	2											2			
39	1	1										1			
40	2											1			
41	1	1		1											
42				1	1										
43		2		2								1			
44		2		2	1										
45		1			1							1			
46		1										1			
47					2										
48	1	1												1	
49		1		3								1			
50		1			1	1									
51							1						1		
52					1		1								
53	1						1								
54	1							1							
55	1							1							
56	1		1		1	1									
57	1					2									
58	2		1			2									
59	5		1			1									
60		1	1			1									
61		1				1									
62			1			1									
63	1		1			1									
64	1	2				1									
65	1					1							1	4	
66			1	2								2			
67			1		1		2								
68			3			1									
69			1	2								2			

MODEL	MOTIF 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
70			1		1	1	1								
71	4		1				4								
72	1		1		2	1	2								
73	3		1			1	1					1			
74	2					1									
75									1						
76						1	1								
77				1											
78									1						
79	1								1						
80			1						2						
81									2						
82				2		1			2						
83	1								1						
84	2						1								
85	2		2			1			2						
86	3						1	1							
87			1						1						
88										1					
89						1				1					
90										1	1				
91						1				2					
92										1	1				1
93										3	1				1
94										2	1				1
95	1						1								
96															1
97							1								1
98															
99														2	
100															
A-1	1									1		1			
A-2											1				
A-3	1						1	1							

CHAPTER III
SYSTEM MODELS

In this part, the hundred systems existing in the known Kitāb-al Ḥiyal manuscripts and three fragments which are contributed to the same work, are described and the corresponding models are derived. According to F. Hauser [6] and Donald R. Hill [8] the systems, which are systematically ordered in the original work, are numbered from 1 to 100. The additional three systems are given in the appendix and named as A-1, A-2 and A-3.

After a short definition of the systems, the art of working these systems is studied. Since, it is intended to derive the system models, in place of an exact translation, only the working principles of the systems are given. For an exact English translation of this work rafer to reference [8]. Finally, a system model is obtained according to the basic motif models and the working art. The derived dynamic system model is generally the simplest one.

In the original work each system is explained by means of a figure. Here, next to each model, a copy of this original figure is given. In the figures the erroneous or missing parts are drawn in cutted lines. The incomprehensible figures are supported by reconstruction or detail figures. The original figures are taken from the oldest and most reliable Topkapı manuscript. The missing figures are taken from the other known manuscripts. The figures taken from Topkapı manuscript are marked

LETTER	OKUNUŞ	KARŞILIK	LETTER	OKUNUŞ	KARŞILIK	LETTER	OKUNUŞ	KARŞILIK
ا	elif	a	ر	re	r	ف	fe	f
ب	be	b	ز	ze	z	ق	kaf	k
ت	te	t	س	sin	s	ك	kef	k̇
ث	se	ṡ	ش	şın	ş	ل	le	l
ج	cim	c	ص	sad	ṣ	م	mim	m
ح	h̄e	h	ض	dat	ḍ	ن	nun	n
خ	hı	ḥ	ط	tı	ṭ	ه	he	e
د	dal	d	ظ	zı	ẓ	و	vav	v
ذ	zal	z̲	ع	ayın	ạ	ى	ye	y

Arabic Letters used in the figures

by (T), the Vatikan manuscript by (V), the Berlin manuscript by (B) and the Leiden manuscript by (L). The transliteration of the Arabic letters used in the original figures is given in the following table.

Model 1-A Cup that Discharges When the Contained Liquid Reaches a Certain Level (Figure 1-a)

This cup, which illustrates one of the basic motifs of the book, discharges with the help of a siphon (see motif 1). When the level of the liquid in the cup **a-b-d** reaches the point **c,** then the siphon **v-e-c-d** pours out the contained liquid. The block diagram of the system is shown in Figure 1-b, in which q_g is the flowrate of the inpouring, $q_ç$ the flowrate of the outpouring liquid, **A** the medium cross section of the cup and **h** the level of the liquid in the cup. In the nonlinear block of the siphon the c-level of the liquid is shown as h_c.

Model 2-An Ewer That Makes Only One Ablution Possible (Figure 2-a)

When the ewer is full and tilted forward it pours out water only for once. If the pouring is stopped the ewer will not pour out water unless refilled.

The effect is reached as such: the water is filled through the pipe **z-h** which runs down towards the handle of the ewer. When the level of the water in the ewer reaches the end **c** of the siphon, the air escape is prevented and this ends the filling. When the ewer is held from the handle and tilted down towards the spout as shown in Figure 2-b, the contained water is discharged by the siphon **v-e-c-k**. If this action is stopped and the ewer is placed upwards, the water in the siphon pours down into the ewer (Figure 2-c). When the ewer is raised and tilted down again for another pouring, the water does not run out since the water does not reach the end **c** of the siphon any more. The block diagram of the system is shown in Figure 2-d. In the diagram the tilting of the ewer for pouring is symbolized by a switch. As in the first system, the flowrate of the inpouring and outpouring water is q_g and $q_ç$, the level of the water in the ewer is **h** and the medium cross section of the ewer is **A**.

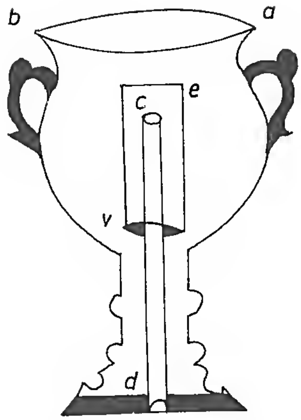


Figure 1-a (T)

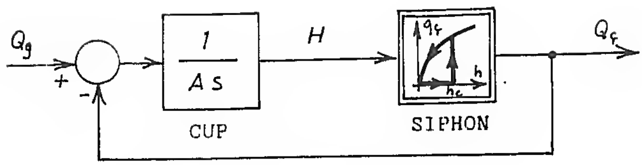


Figure 1-b

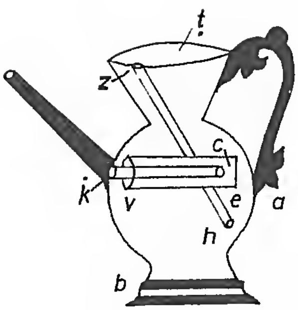


Figure 2-a (T)

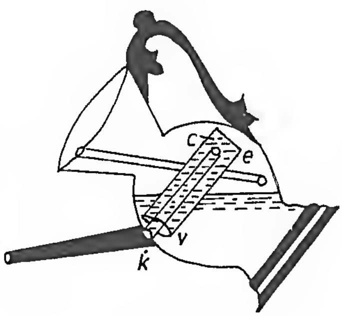


Figure 2-b

Figure 2-c

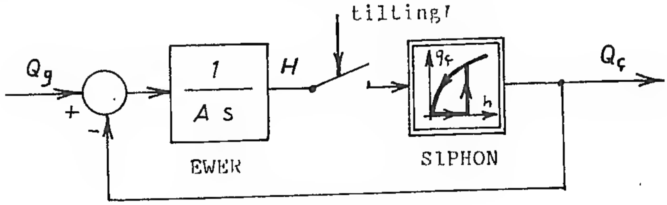


Figure 2-d

Model 3-A Pitcher that can be Filled if the Liquid is Poured in Continuously, but Once the Filling is Interrupted, It Will Receive No More (Figure 3-a)

The effect aimed in this system is reached by a double concentric siphon (see Motif 2). The liquid is poured through the hole **ḥ**. At the upper tank, which is in the neck of the pitcher, a double concentric siphon extends in the pitcher. When the level of the liquid in the upper tank reaches the point **ṭ**, it pours into the pitcher through a double concentric siphon **ṭ-y-v** (in the Figure the cap of the upper siphon is not shown.). The filling continues all the time that the liquid is poured through the hole **ḥ** and the pitcher is not full. If the filling is interrupted for a while, some liquid retains under the level-**ṭ** of the upper and the level-**k̇** of the under concentric siphon. When filling ends the pitcher refuses to accept the liquid because the pressure of the liquid entering the upper siphon is not enough to push the liquid retained in the under concentric siphon.

The model of the double concentric siphon used in this system is realised by "and", "or" and "S-R memory" elements (Figure 3-b). In the block diagram of the system given in Figure 3-c, it is impossible to start refilling because after an interruption the double concentric siphon opens the switch in the upper tank. A new filling can only be done if a $x_1=1$ winding sign, meaning the siphon has been emptied, is applied. The x_2 signal which triggers the system is formed by the "filling" and "empty pitcher" signals. In the model, q_g and $q_ç$ are the flowrates of the inpouring and outpouring liquid, h_1 is the level the liquid in the upper tank, h_2 is the level of the liquid in the pitcher, A_1 and A_2 are the medium cross sections of the upper tank and the pitcher, q_1 is the flowrate of the liquid flowing through the siphon.

Model 4-A Pitcher Which Will Not Pour Out While Water is Fed In, but as soon as the Filling is Interrupted or Finished, It Will Restart Pouring Out the Contained Water (Figure 4-a)

The aimed effect is achieved by a buoy with a closing valve (see Motif 4). The poured water flows first through the pipe **ṭ-h** into the tank **m**

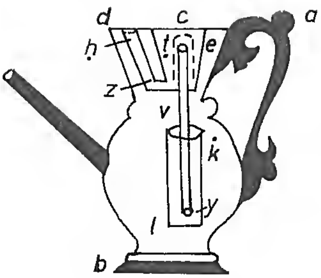


Figure 3-a (T)

t	x_1	x_2	y
t_1	1	0	1
t_2	0	0	1
t_3	0	1	1
t_4	0	0	0

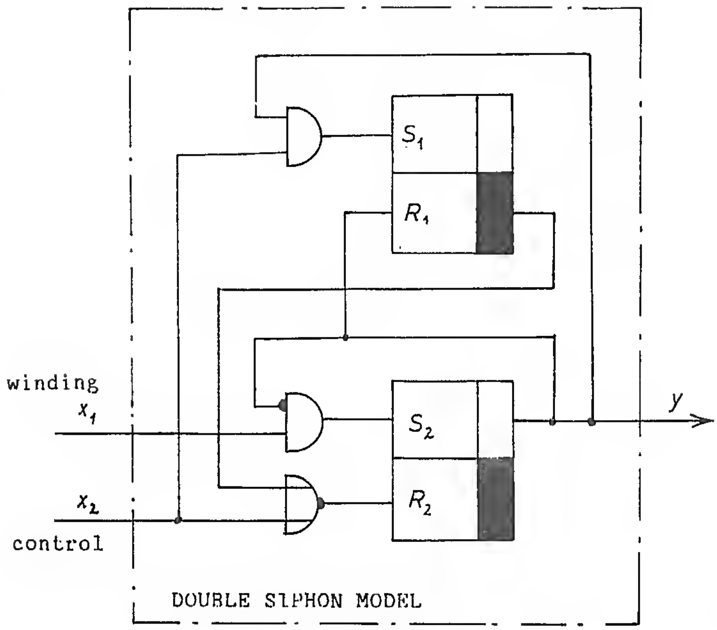


Figure 3-b

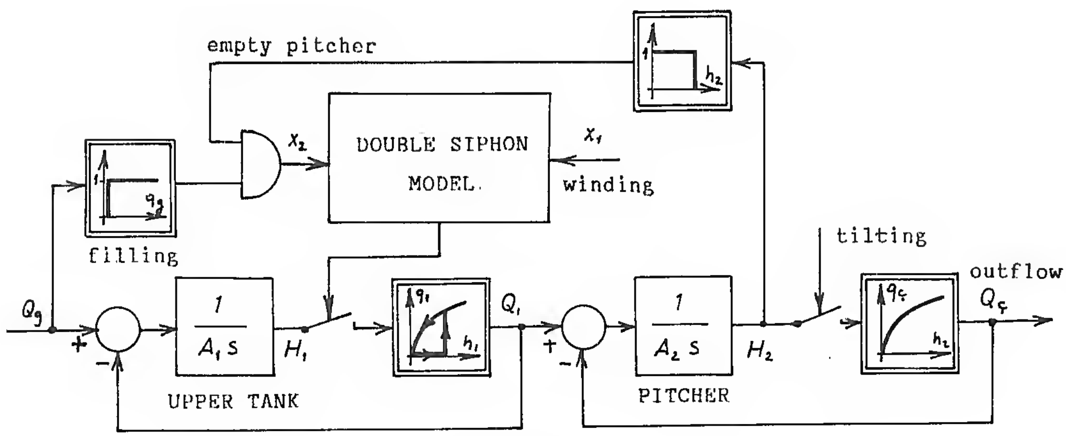


Figure 3-c

- **v**. The buoy **e** in the tank raises and the valve **k̇-d-l** which is on the arm **z** plugs the discharging pipe. The water which is poured uninterrupted into the system overflows the tank **m** and collects in the intermediate partition **n-ş**. When the filling is interrupted or finished the siphon **v-f-ạ** empties the water in tank **m** and with the lowering of the buoy's level the connected valve **d** opens. Thus, the water in the intermediate partition **n-ş** pours out from the pipe **y - c**, till the water finishes or refilling is restarted.

The block diagram of this system corresponding to a logic negation can be seen in Figure 4-b.

Model 5-On a Box, a Lion and Two Antelopes are Waiting Tilted Towards Their Cups; if Water is Poured into the Cups in Front of the Antelopes, They Can Drink the Water Only if Water is Also Poured into the Lion's Cup and the Lion Has Finished Drinking it (Figure 5-a)

On the top of a box **a - b**, a lion and two antelopes are sitting tilted towards their cups in front. The water which is poured into the antelopes' cups flows also through the pipes **c-c-k̇**, beginning inside the antelopes' mouths and ending in the tank **e - k̇**, closed at the bottom with the valve **k̇ - v**. When water is also poured into the cup in front of the lion and the level of this water raises the upper level of the siphon inside the lion's mouth, the water in the cup runs into the tank **h** inside the lion. With the rise of the buoy **z** in the tank **h**, a handle which is tied to the buoy opens the valve **v**. Thus, as soon as the lion "drinks" his water the antelopes could also "drink" theirs. The water of the tank **h** inside the lion runs into the box following the pipe **ţ-v** through the hole **ţ**. When the level of the buoy **z** drops, the valve **v** tied to the buoy closes and the system returns to its first position.

As is seen from Figure 5-b the system reacts like succesive connected "or" and "and" logic elements. Another block diagram which also evaluates the dynamics of the system is shown in Figure 5-c. In this block diagram q_1 is the flowrate of the water pouring into the lion's cup, q_{31} and q_{32} the flowrate of the water pouring into the antelops' cups, q_3 the flowrate of the water pouring into the tank **h**, $q_ç = q_4 + q_5$

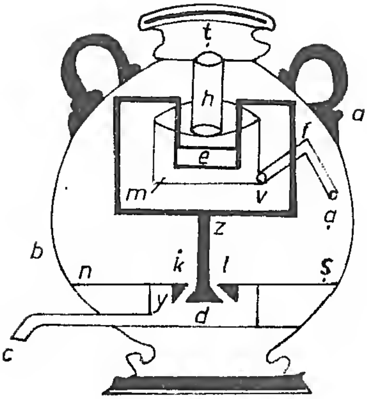


Figure 4-a (T)

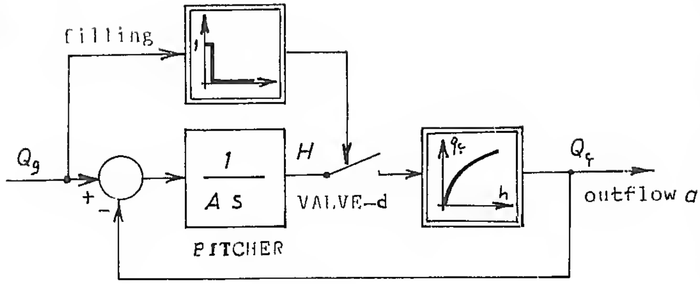


Figure 4-b

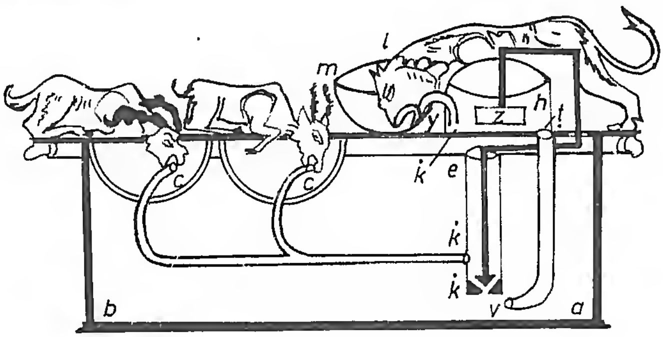


Figure 5-a (T)

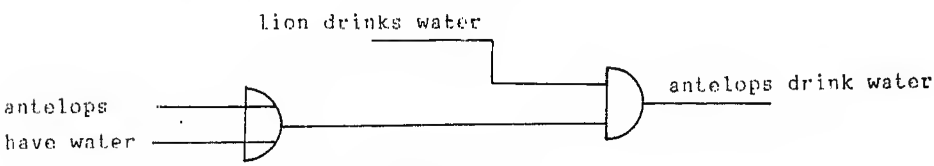


Figure 5-b

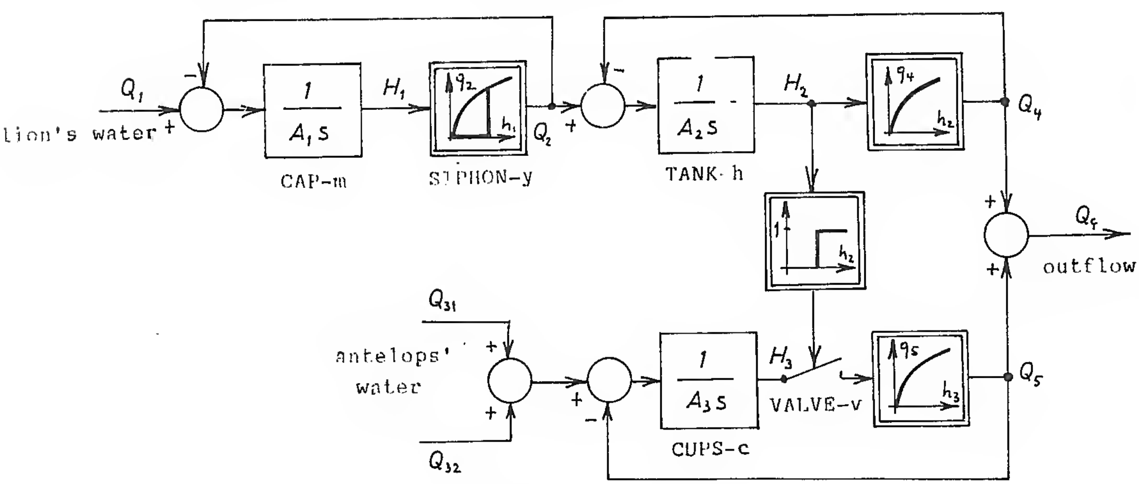


Figure 5-c

the flowrate of the water collected in the box; A_1 and h_1 are the lion's cup, A_2 and h_2 the h-tank's, A_3 and h_3 the antelopes' cups cross section and water level.

Model 6-A Bull Who Drinks the Water Poured in the Vessel in front of it and Makes a Voice of Contentment as if it's Thirst is Satisfied (Figure 6-a)

A bull standing on top of a box inserts his mouth into the vessel **s**. When water is poured into the vessel, the buoy **m** inside the vessel rises and a chain that is tied to it running along a pipe over the pulleys **l-v** opens the valve **e** in the box. Due to the unclear drawing of this mechanism, a reconstruction is given in Figure 6-b. With the opening of the valve **e** the water that is filled through the tap **a** into the upper partition **a-e-k̇** of the box runs into the tank **ṭ-z**. This rises the buoy **y** in the tank which opens the valve **k̇**. The water emptied from the tank **ṭ-z** forms an air vacuum in the upper tank. This air vacuum sucks the water into the vessel s in front of the bull with noise and this is perceived as the thirstiness of the bull. While the water in the tank **ṭ - z** runs through the hole **ṭ** into the bottom of the box, the air in this part goes out through the hole **c**.

In the block diagram given in Figure 6-c, the level h_2 of the vessel s is the signal which triggers the system. The system is similar to an electric circuit which is stepwise overthrown. The event of sucking water from the vessel under pressure, after the valve **e** and then the valve **k̇** opens, is modeled by a multiplying element.

Model 7-A Trough of Approximately 2 Liters of Water That Preserves its Level, Even if 20 Small Animals Drink Water From it, but Loses All its Water When a Bull Drinks (Figure 7-a)

Water is fed into the tank at the ba of the trough by the tab **b**. When the level of water in the tank **a-b** reaches the end **ṡ** of the siphon **k̇-ṡ**, the water runs through the pipe **ṡ-c** and the valve **c** into the tank **e-l-z** (at the beginning the valve **ṭ** is closed). The level of water in this tank rises until the lower end **d** of the pipe **a-d** is plugged with water or the entrance of air into the tank **a-b** is prevented. After the

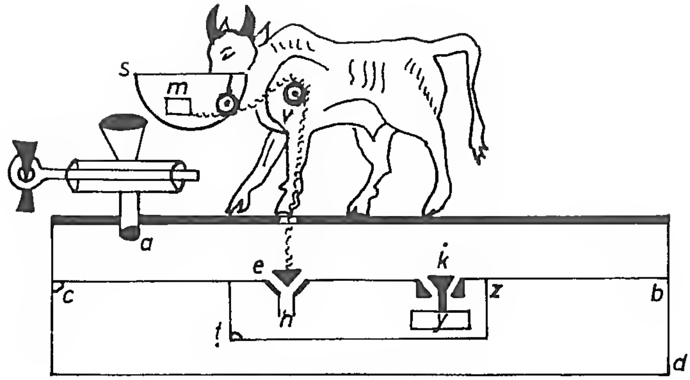


Figure 6-a (T)

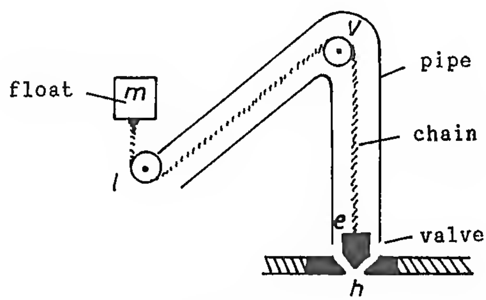


Figure 6-b

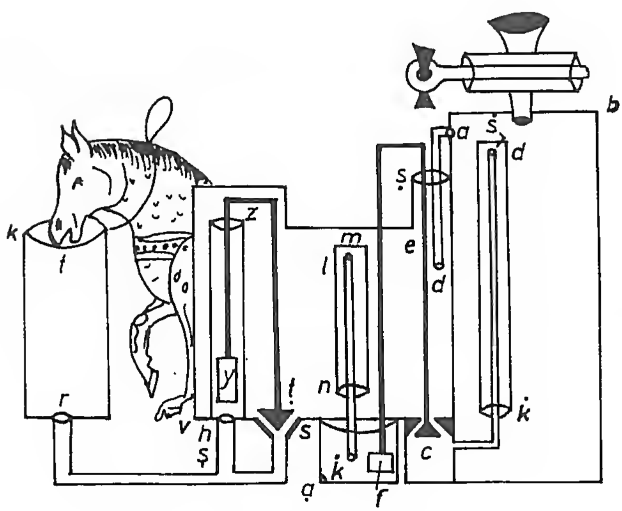


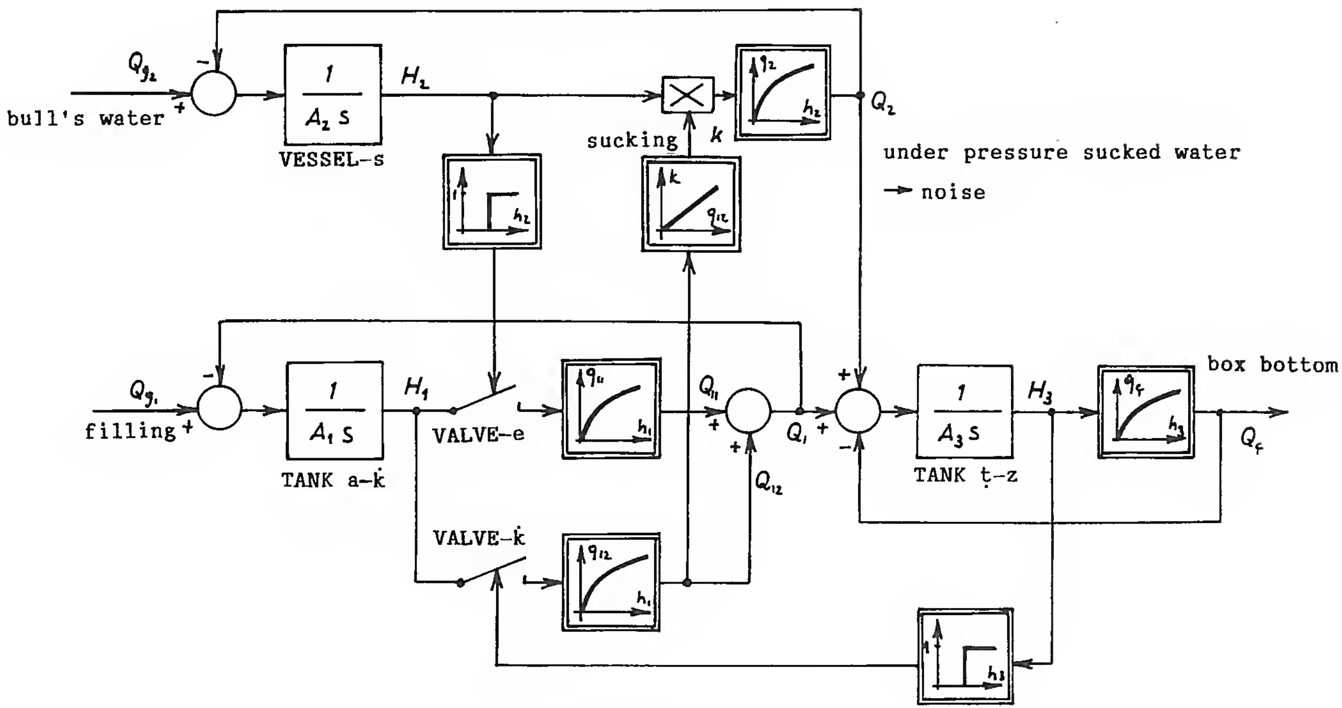
Figure 7-a (T)

filling is finished and the airtight tab **b** is closed, some water is also poured into the trough **k-t-r** from which the animals drink. Some of the water that is poured into the trough goes through the pipe **r-ş** and rises the buoy **y** in the tank **h-z.** By this way the valve **ţ** opens and a connection between the trough **k-t-r** and the tank **e-l-z** is obtained. Thus, the water level in the trough rises up to the level of the tank **e-l-z.** As requested when small animals drink water from the trough the level of the trough and the tank is continuously regulated by the amount of air which passes through the pipe **d-a** to tank **a-b.**

If a big animal like a horse or a bull puts his mouth into the trough **k-t** for a drink, the level of water in the tank **e-l-z** raises for a moment with the amount of water that the animal splashes back with his mouth. When the level of the water in the tank **e-l-z** rises over the level **l** of the siphon **n-l**, the water in the tank quickly starts running over the siphon **n-l-m-k̇** into the tank **k̇.** At the same moment the buoy **f** which is in the tank **k̇** rises and closes the valve **c.** Thus, the regulating of the water level in the tanks **a-b** and **e-l-z** and the trough **k-t-r** is prevented. All the water in the trough **k-t-r** and the tank **e-l-z** empties down to the level **r-v-s.** Also, the buoy **y** drops and removes the connection between the trough and the tank.

The water poured into the tank **k̇** flows out through the hole **ạ** at the bottom of the tank. When the tank **k̇** empties out after a while, the buoy **f** drops, the valve **c** opens, and the level of the water in the tank **e-l-z** begins to be controlled again from the tank **a-b.** In order to put the trough **k-t-r** in connection with the tank some water must be poured into the trough from outside. By this water the buoy **y** raises and the valve **ţ** reopens.

The block diagram of this complicated automatic control system can be seen in Figure 7-b. The automatic control loop is formed by the control of the air. The connecting of the tank to the trough and the blocking of the control loop is realised by the motif of buoyed valves (see Motif 4).



Q_{g_2}
bull's water
$\frac{1}{A_2 s}$
VESSEL-s
H_2
sucking
k
Q_2
under pressure sucked water
→ noise
Q_{g_1}
filling
$\frac{1}{A_1 s}$
TANK a-k̇
H_1
VALVE-e
VALVE-k̇
Q_{11}
Q_{12}
Q_1
$\frac{1}{A_3 s}$
TANK ṭ-z
H_3
box bottom
Q_f

Figure 6-c

Model 8-A-Pitcher That Can Be Filled if Water is Poured in Continuously and Will Receive Nothing if Filling is Interrupted Unless it is Emptied (Figure 8-a)

The water which is poured into the upper tank on the neck of the pitcher, goes through the pipe **d-e** and the valve **v**, than flows into the tank **n.** When the level of the water in this tank rises over the upper edge of the siphon **h**, the water pours into the buoyed tank **ş-s** and after this the tank is also overflown, the water collects at the bottom of the pitcher. The weight of the tank **n** full of water, keeps the buoy **ţ** down in the tank **ş-s**. If the filling of the pitcher is finished or interrupted for a moment the buoy **ţ** rises and the valve **v** closes because the siphon **h** empties the water of the tank **n**. So the pitcher cannot be filled any more unless the water in the tank **s** is emptied.

This model is an application of the valve with a buoyed tank motif (see Motif 5). As it is seen from the block diagram in Figure 8-b, the valve is controlled by a logic circuit. The valve **v** is closed ($z=0$) only if the tank **n** is empty ($x_1=1$) and the tank s is full ($x_2=1$). At this state filling can not be realised, but in all other conditions the filling of the pitcher is possible.

Model 9-A Pitcher That Accepts Only One Interruption and Will Not Receive Any More Unless It is Emptied (Figure 9-a)

In this system the valve with a buoyed tank motif which has been used in the previous model is used twice. The water that is poured into the system first goes through the track **d-v**, passing through the valve **v** and the siphon **h** that is in the tank **n**, and pours at last into the tank **ţ-s.** After the first interruption the siphon **h** empties the tank **n** and with the rising of the buoy **ţ** the valve **v** closes. During the second pouring, the water takes the track **m-ạ**; it flows through the valve **ạ** and through the siphon **ḳ** in the tank **f**, and pours at last into the tank **k-ş**. After the second interruption, the siphon **ḳ** empties the tank **f** and with the rising of the buoy **k** the valve **ạ** also gets closed. To refill the pitcher, the tanks containing the buoys have to be emptied.

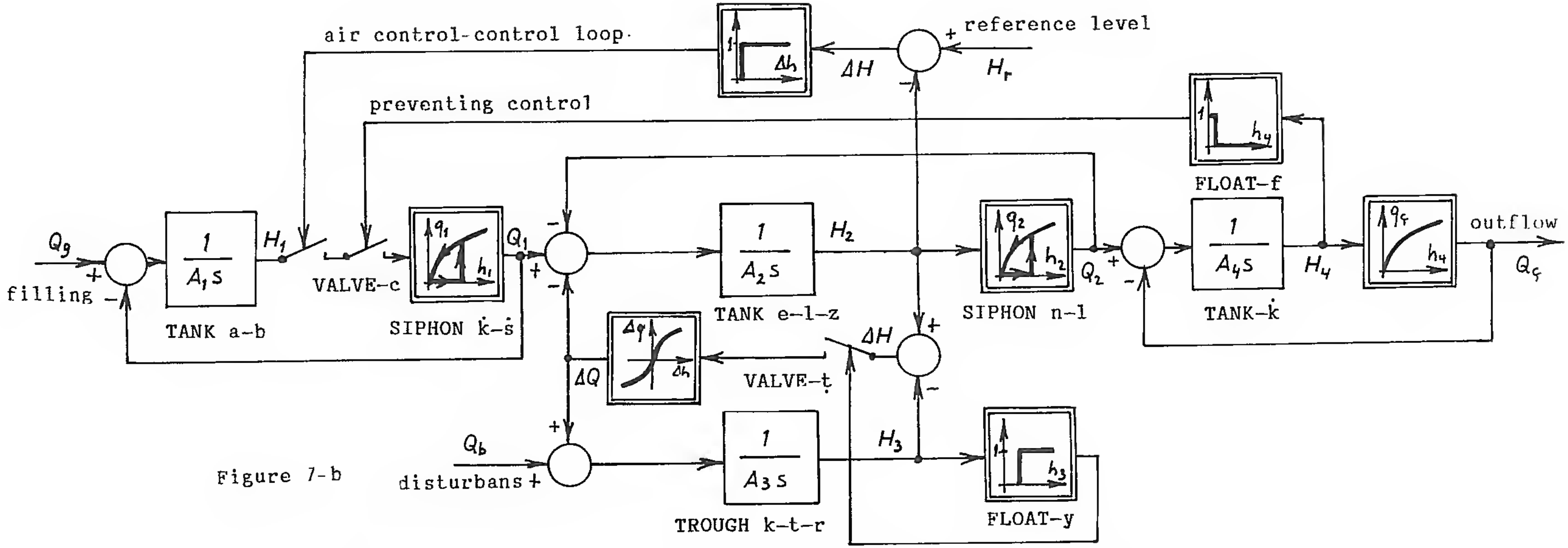


Figure 7-b

x_1	x_2	Z
1	0	1
0	0	1
0	1	1
1	1	0

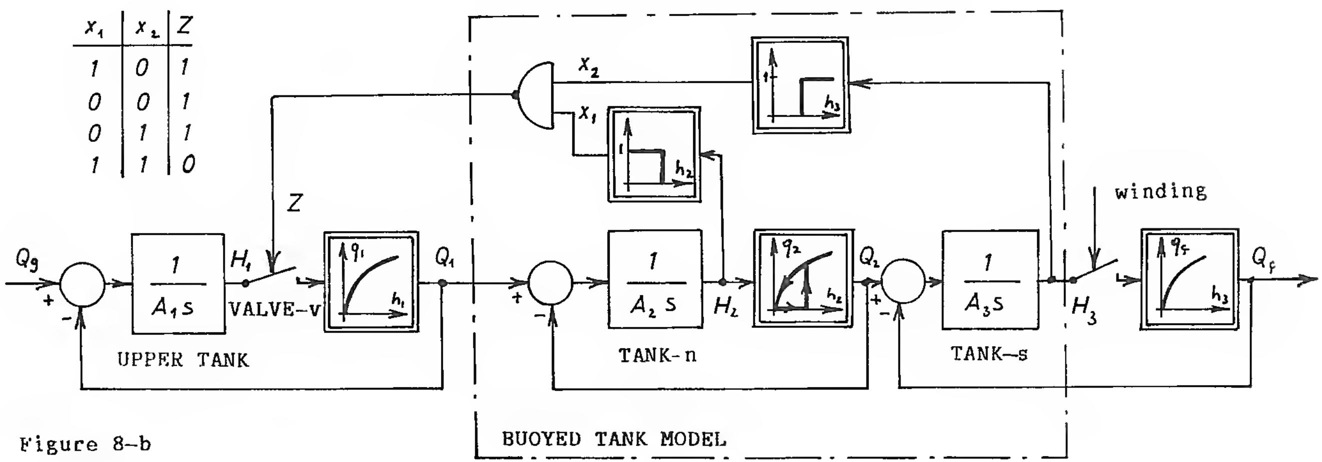


Figure 8-b

The block diagram of the system is given in Figure 9-b. The coordination of the buoyed tanks is modelled by the logic elemenent "and". For the second buoyed tank to be open (z=1), the valve of the first buoyed tank has to be closed ($z_1=0$) and the second buoyed tank has to be empty ($z_2=1$).

Model 10-Another Pitcher (see Model 8) **Which Does Not Accept Interruption While Pouring in Water and When the Filling is Interrupted Cannot be Refilled Unless It is Emptied** (Figure 10-a)

The water that is poured into the pitcher from the pipe **a-b** runs through the valve **z** into the tank **e-h**. The pipe **e-v-d** at the bottom of the tank **e-h** which forms the arm of a balance (see reconstruction figure 10-b) pours the water into the tank **d-c**. When the tank **d-c** fills, the water overflows into the bottom of the pitcher. The tanks **e-h** and **c-d** which are balanced at the point **v** along with the zalve **z** form a "valved balance" (see Motif 6). During the time the tank **e-h** is full of water the balance is tilted right and the valve **z** attached to the balance is open. If filling is interrupted, due to the difference in levels, the water in the tank **e-h** empties over the pipe **e-v-d** into the tank **c-d**, thus the balance tilts left closing the valve **z**. If one wishes to refill water into the pitcher the tank **c-d** has to be emptied.

The block diagram of the system is given in Figure 10-c. As seen that in order to have the valve z closed (z=0), the tank **e-h** has to be empty ($x_1=0$) and the tank **c-d** has to be full ($x_2=1$).

Model 11-Another Pitcher (see Model 9) **That Accepts Only One Interruption and Will Not Receive Anymore Unless It is Emptied** (Figure 11-a)

In the pitcher, the water runs first through the pipe **a-b** into the tank **b** that contain two "double siphons". When the level in the tank **b** reaches point **e** the double siphon **c-e-h-ţ** passes the water into the pitcher. After the first interruption this double siphon does not accept a second pass (see Motif 2). A second filling can be realised by the double siphon **d-z-v-y** which has a higher level **z**. After the second interruption the

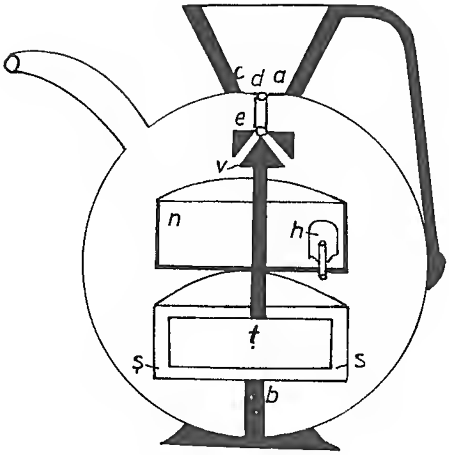


Figure 8-a (V)

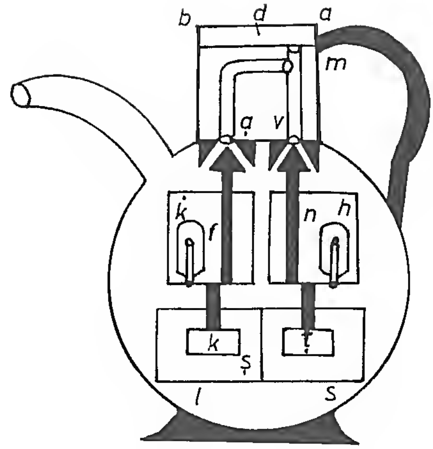


Figure 9-a (V)

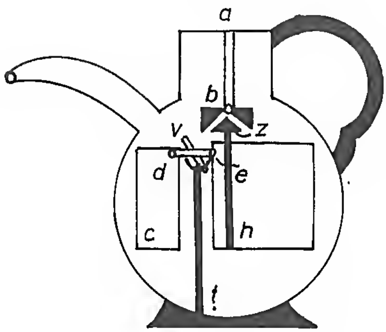


Figure 10-a (V)

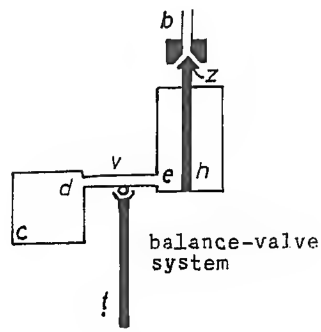


Figure 10-b

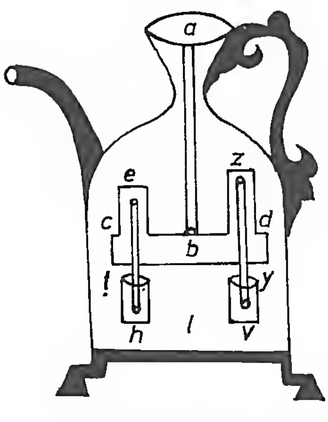


Figure 11-a (T)

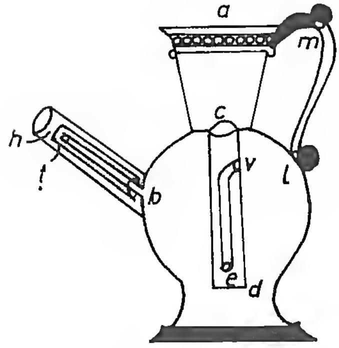
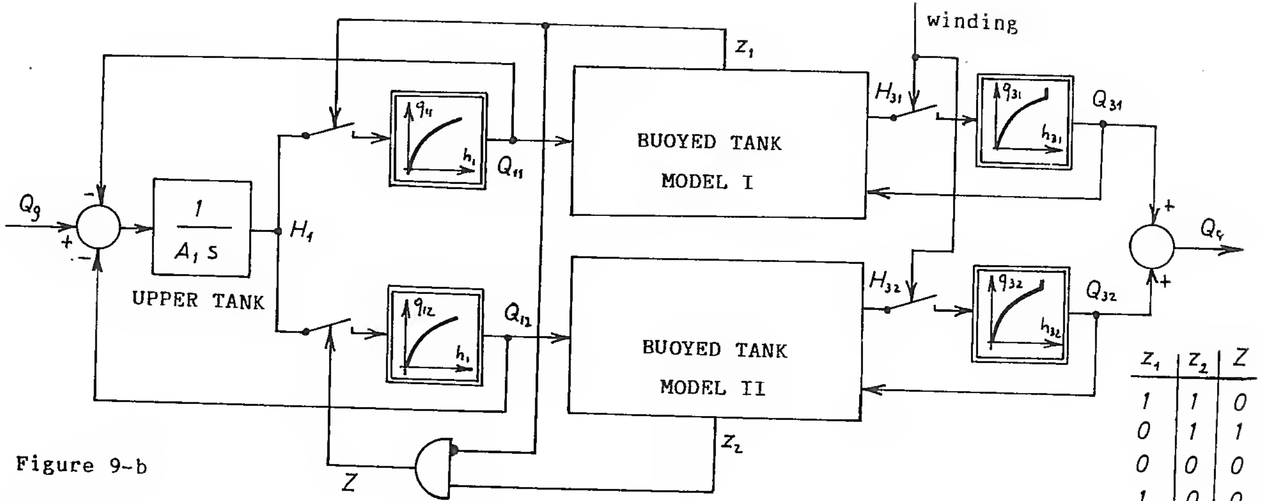


Figure 12-a (T)



Z_1	Z_2	Z
1	1	0
0	1	1
0	0	0
1	0	0

Figure 9-b

X_1	X_2	Z
0	1	1
1	1	1
1	0	1
0	0	0

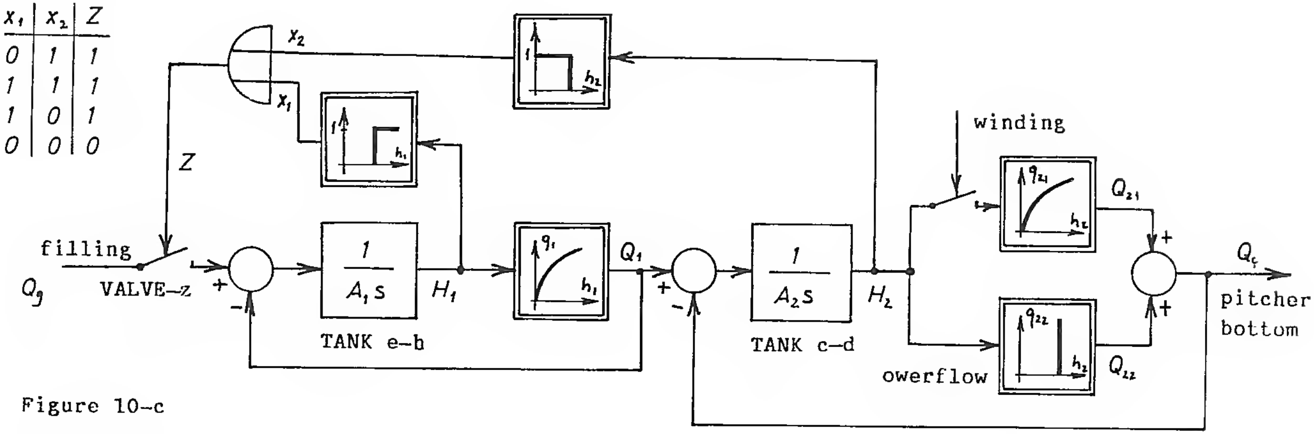
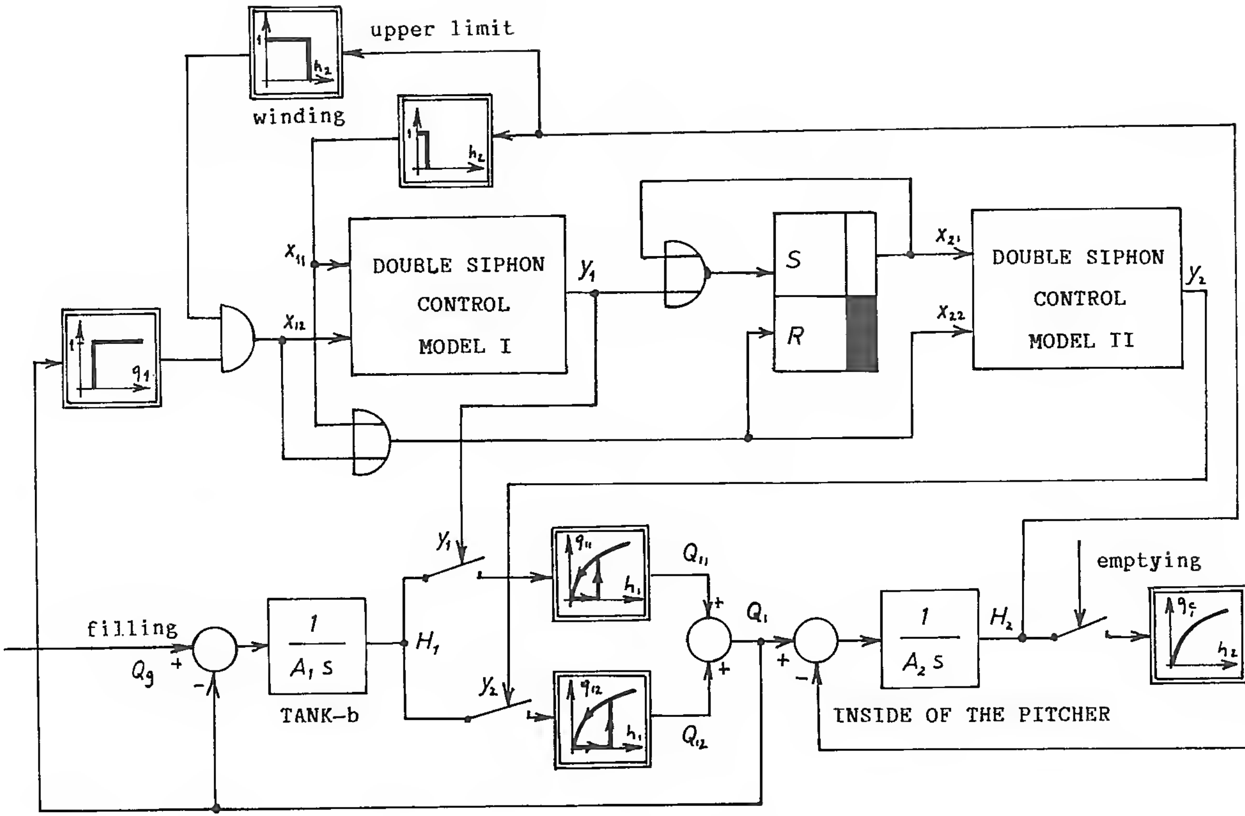


Figure 10-c



t	x_{11}	x_{12}	y_1	x_{21}	x_{22}	y_2
t_1	1	0	1	0	1	0
t_2	0	0	1	0	0	0
t_3	0	1	1	0	1	0
t_4	0	0	0	1	0	1
t_5	0	1	0	0	1	1
t_6	0	0	0	0	0	0

Figure 11–b

siphons **h-ṭ** and **v-y** have to be emptied for a new filling to be realised.

As seen from the block diagram concerning this system, a sequential logic circuit is necessary to work together with the double siphon control model (Figure 11-b). The filling flowrate q_1 (at the beginning $y_1 = 1$) and the level h_2 which determines the emptiness of the pitcher, effect the trigger signal x_{12} of the control model. The same trigger signal x_{22} effects the second double siphon model. But, the trigger signal of the second siphon control model is formed over a S-R memory element which evaluates the output y_1 of the first double siphon. In the picture the truth table of the system logic is given in function of the time **t**.

Model 12-A Pitcher That Would Not Pour out for a "Heretic"
(Figure 12-a)

The water is poured into the pitcher through a perforated lid. Under the lid over a partition at the neck are found the concentric pipes **c-d-e-v**. This does not prevent the flow of water but forms an air obstacle between the upper tank and the inside of the pitcher.

If a slave (gulam) using the pitcher wants to pour water for a washing person, he lets the hoḷe **m** at the handle free. Thus the water in the pitcher pours out through the siphon **b-ṭ-h** in the spout. If he does not want to pour (for a "heretic") then he closes the hole **m** with his thumb or with a piece of wax. When he tilts the pitcher the water does not pour because there is no way for the air to enter and replace the overflown water. If he thinks the pitcher is empty and wants to refill it he cannot fill as long as the hole **m** retains closed, since the remaining water at the bottom of the siphon **b-ṭ** in the spout prevents the escape of the air.

In the block diagram of this system (Figure 12-b) the air control (see Motif 7) and the tilting of the pitcher are taken as input variables. The overflowing of the pitcher is evaluated in the block diagram as a separate feedback.

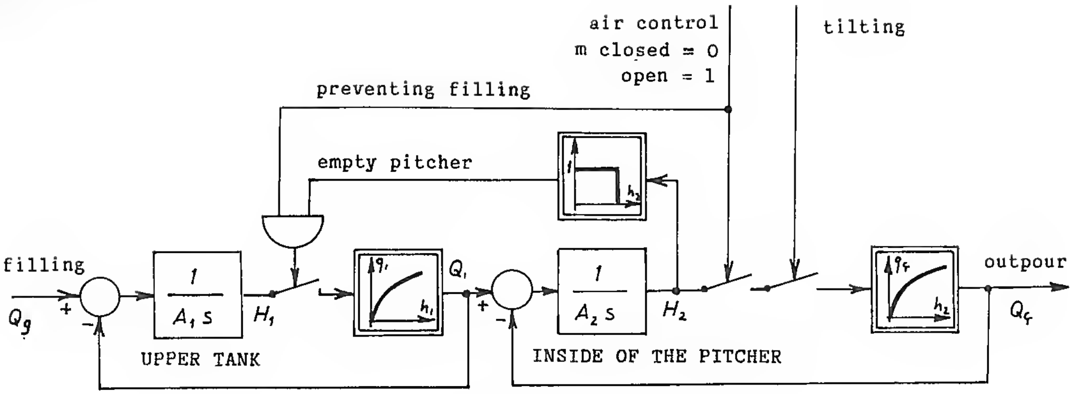


Figure 12-b)

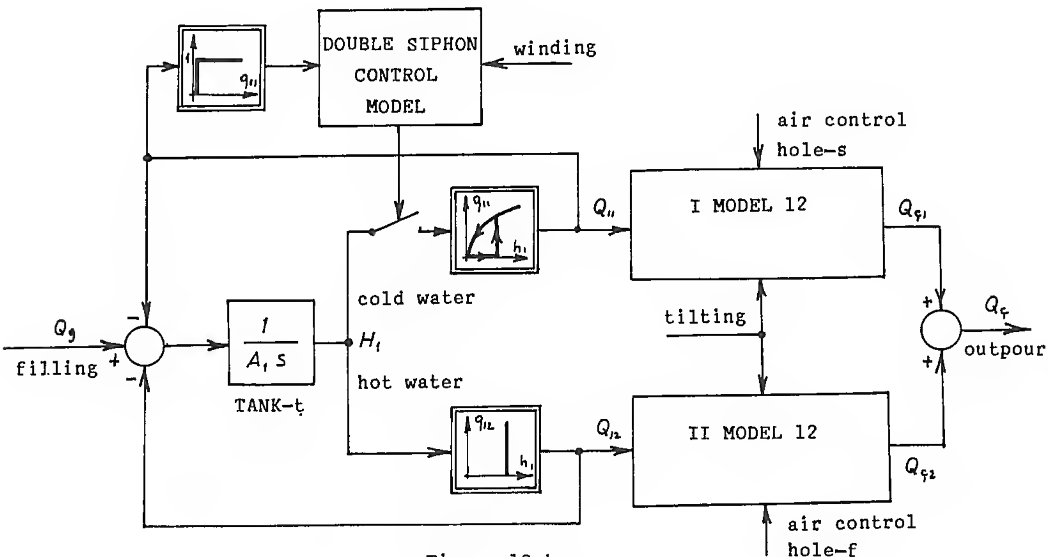


Figure 13-b

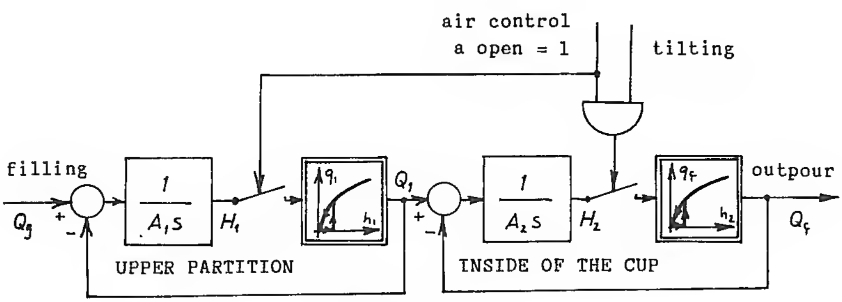


Figure 14-b

Model 13-A Pitcher into Which if Cold and Hot Water is Filled in Succession, They Do Not Get Mixed and One Can Pour Out Water in Any Desired Warmth (Figure 13-a)

First the cold water is poured continuously into the pitcher through the hole **a**. The water runs the track **ţ-h-e-l-ķ** and collects at the bottom of the pitcher. After a short interruption the hot water is poured. As the double siphon **h-e** does not pass anymore, the hot water running from the overflowing pipe **b-v**, that is on a higher level, follows the track **v-z-c** and collects on the upper partition of the pitcher. At the end of the filling due to the air obstacles **l-ķ**, **z-c**, **ş-t** and **s-ṡ** both of the partitions have air contact only with the outside through the holes s and **f** which are on the handle of the pitcher. By opening or closing the holes s and **f** one can regulate the hotness, coldness and warmth of the outpouring water or stop the outpouring completely.

In this application Model 12 is used twice. As seen in the block diagram (Figure 13-b) the separation and the control of the liquids is realised by using a double siphon motif (see Motif 2) and the air control motif (see Motif 7).

Model 14-A Cup That Misleads the Observer During Filling and Emptying (Figure 14-a)

This cup has, over the partition **ţ-h** on the neck, a little double siphon **d**. If the hole **a** at the handle of the cup is closed, this double siphon witholds the filling even if the cup is empty or witholds the emptying even if the cup is full of water. The length of the double siphon is short, for this reason this motif shows the effect of a double direction siphon due to the liquid pressure (see Motif 2). The user of the cup, by opening or closing the hole **a**, could fill in or pour out the desired amount of water.

The block diagram of the system is given in Figure 14-b. The double siphon **d** which shows the effect of a siphon is drawn twice in the block diagram, once in filling and once in emptying procedure.

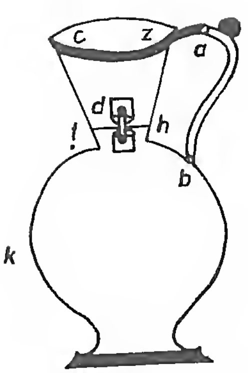


Figure 14-a (T)

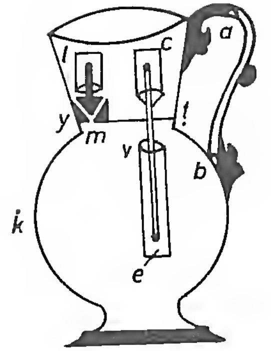


Figure 15-a (T)

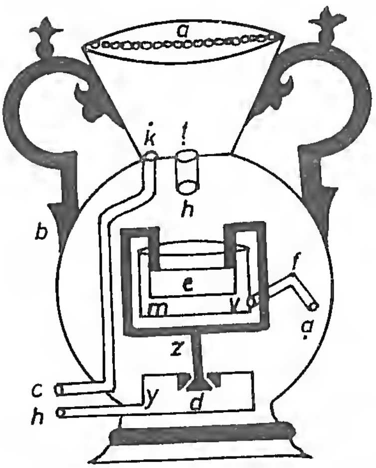


Figure 16-a (T)

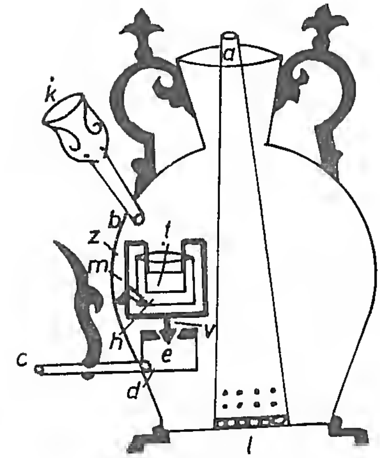


Figure 17-a (T)

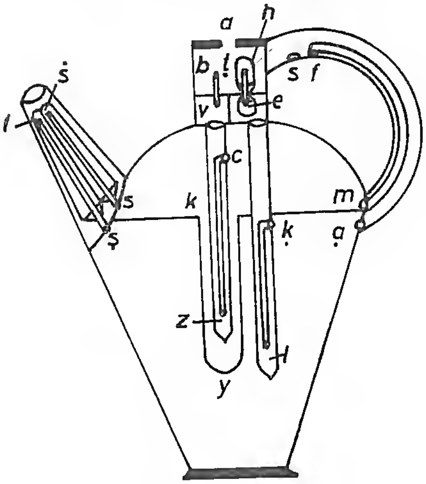


Figure 13-a (V)

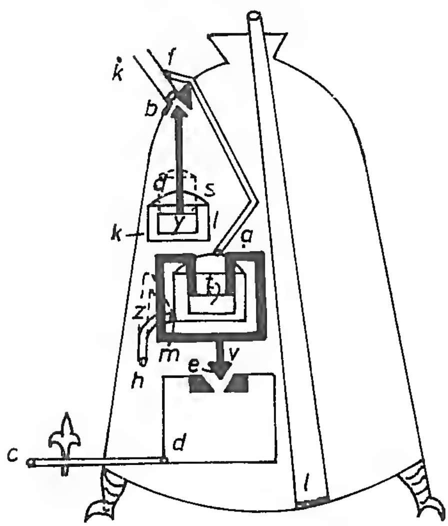


Figure 18-a (V)

Model 15-Another Cup (see Model 14) **That Misleads the Observer While Filling or Emptying** (Figure 15-a)

The liquid poured into the cup, since the valve **m** in the middle partition of the neck is in the normal position closed, goes through the double siphon **c-e-v** and collects at the bottom of the cup. During pouring, the air found in the cup goes out through the hole **a.** In order to give the impression of a full cup either the hole **a** is closed or the act of pouring is interrupted for a little while. In the first case the filling is no more possible because air cannot escape, and in the second case the double siphon effect (see Motifs 2 and 7) prevents the filling. If one wants to pour liquid out of the cup, the cup has to be tilted. In this position the valve **m**, which has its bearing in **l**, opens and as long as the hole **a** is open the liquid flows out.

The block diagram concerning this model is given in Figure 15-b. This system differs from Model 14 in two aspects: first the double siphon is in such a dimension that it can affect its normal function; secondly the act of emptying is realised by air control using the valve **m.**

Model 16-A Jar With Two Outlets: While Liquid is Being Poured in, It Flows From One of the Outlets and if Pouring is Interrupted or Finished the Liquid Starts to Flow Out From the Other Outlet (Figure 16-a)

The liquid is poured into the jar through the lid **a** which is perforated like a sieve. In the neck of the jar there is a partition **ḳ-ṭ** and two pipes connected to it. The pipe **ḳ-c** which has a smaller cross section compared to the other pipe, empties out a part of the liquid poured to the partition. The liquid running through the pipe **ṭ-h** which has a larger cross section pours into the tank **m-v** that contains a floated valve (see Motif 4). All the while the liquid is poured into the jar, the float **e** rises and closes the valve **d** that is tied to it. Thus the liquid cannot run out through the pipe **y-h**. When the filling is interrupted or ended, the siphon **v-f-ạ** empties the tank **m-v** and the float **e** sinks opening the valve **d.** Thus the liquid gathered in the jar flows out through the track **d-y-h.**

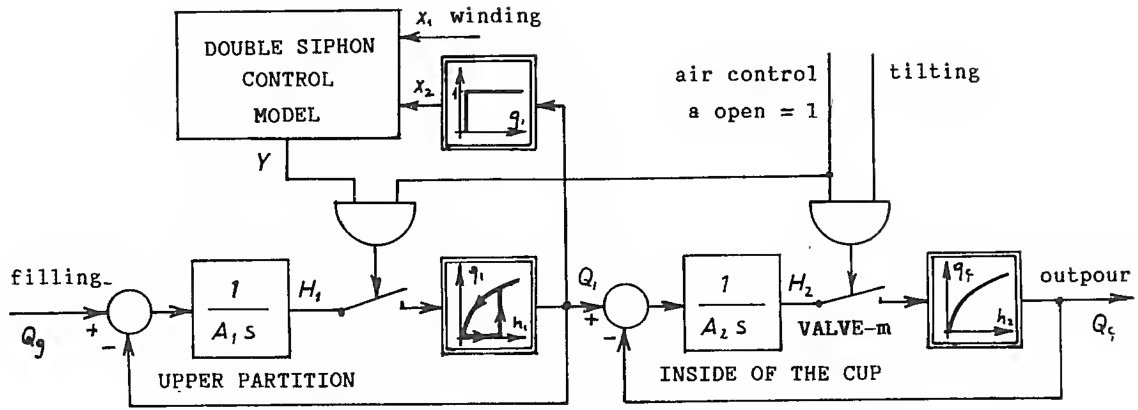


Figure 15-b

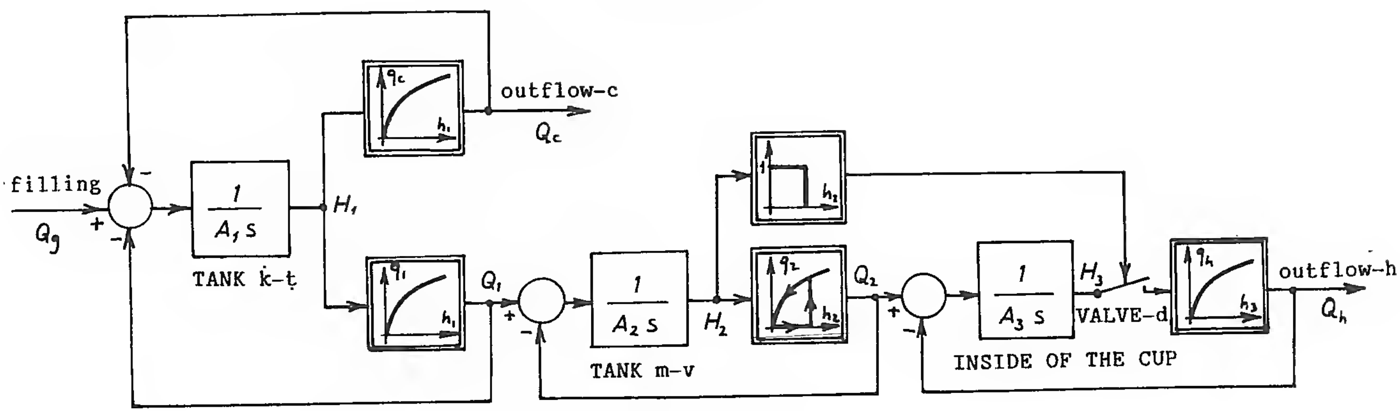


Figure 16-b

The block diagram of the system is seen in Figure 16-b. In this model the closing floated valve corresponds to a logic negation (output **c** is contrary to the output **h** or **c**= $\bar{\mathbf{h}}$).

Model 17-A Boiler That Gives Out Hot Water as Cold Water is Poured In (Figure 17-a)

The flame of the fire in the pipe **a-l**, which goes through the middle of the boiler, warms the surrounding water. The cold water is filled in the boiler through funnel **k**. The water running through the funnel first runs into the tank **h** which contains a floated valve. Contrary to the Model 16 the valve **e** is of opening type. This ensures that the same amount of warm water as the cold water put into the boiler flows into the tank **e**. As the filling ends the tank **h** containing a siphon empties and with the sinking of the float **ţ** the valve **e** closes. The hot water in the tank **e** can be poured out by opening tap **c** at the desired time and intervals.

The block diagram of the system (see Figure 17-b) is formed by an opening type floated valve (see Motif 4) and a tank with a tap (see Motif 12).

Model 18-Another Boiler (see Model 17) **That Can Also Be Filled When the Tap is Open** (Figure 18-a)

This boiler, with a better filling mechanism, is an improvement of Model 17. In the previous model the tap **c** has to be kept closed, because the tank **e** fills up during the first filling. However, in this boiler, the water enters through the valve **b** which is controlled with a floated tank (see Motif 5). After one first interruption or the ending of the filling, the water of the tank **d** that is above the float **y** empties through the hole **s** in the tank **l** and the float rises closing the valve **b** (in the original figure the floated tank **d** has not been drawn). Since the valve **e** is closed during this procedure, the tap **c** can be kept open. If refilling is wanted, then the water runs through the track **k-f-ą** and now the system behaves like Model 17.

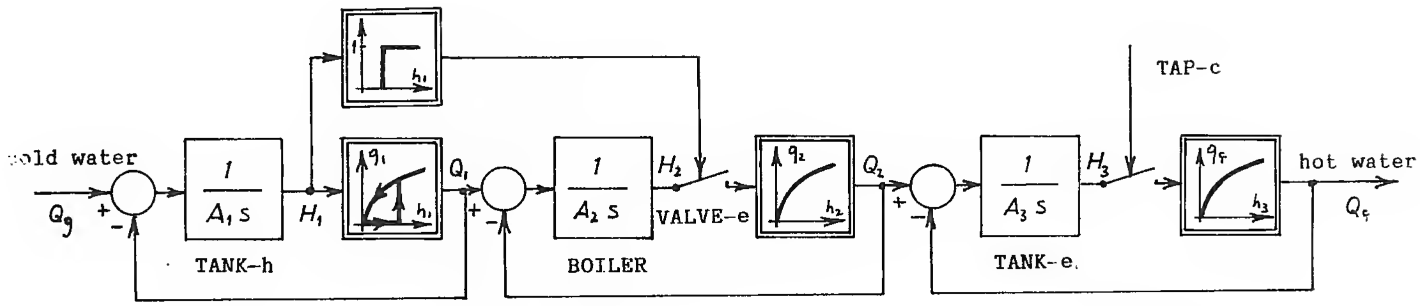


Figure 17-b

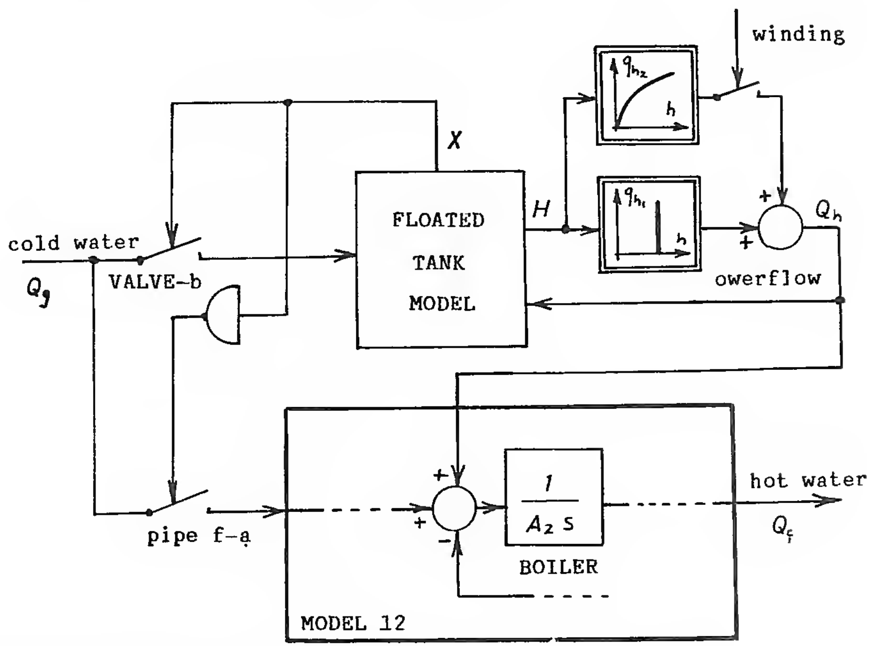


Figure 18-b

The block diagram of the system can be seen in Figure 18-b. In this diagram the model of a valve controlled with a floated tank is added in front of the block diagram of Model 17. The flowrate of the water overflowing the floated tank is added on at the point of addition in front of the boiler block in Model 17.

Model 19-A Jar That When A Certain Quantity of Different Liquids Are Poured In, the Liquids Can Be Extracted Unmixed From A Tap (Figure 19-a)

The liquids are poured into the jar with a measuring cup. The first liquid is filled in the measuring cup to level **c** and then poured into the jar. This liquid first flows into the tank **c** and next runs through the siphon **d** in tank **b** and at last goes through the siphon **e** collecting in tank **a**. The second liquid is put into the measuring cup up to the level **b** and is also poured into the jar. The liquid flows into the tank **c**, then runs through the siphon **d** in tank **b** and stays in this tank because its level does not reach the upper end of siphon **e**. At last, the third liquid which is poured up to level **a** in the measuring cup and then poured into the jar is stored in tank **c** because its level does not reach the upper end of siphon **d**. The user of the jar can pour out the desired liquid according to the position of the tap **s**. If desired, various mixtures of liquids could be obtained by opening appropriate holes in the plug of the tap.

The block diagram of the system is given in Figure 19-b.

Model 20-Another Jar (see Model 19) **in Which When Various Liquids Are Poured in, the Liquids Can Be Extracted Unmixed From A Tap** (Figure 20-a)

There are two double siphons with different levels and a overflow pipe in the upper tank which forms the partition **s-t** at the neck of the jar (see Motif 2). The first liquid that is poured into the jar runs through the double siphon **ţ-l-s** and collects at the tank **v**. The second liquid which is poured after a short interval, goes through the double siphon **y-m-ạ** that has a higher upper level and collects in the tank **z** since the first double siphon is plugged. The third liquid that is poured into the

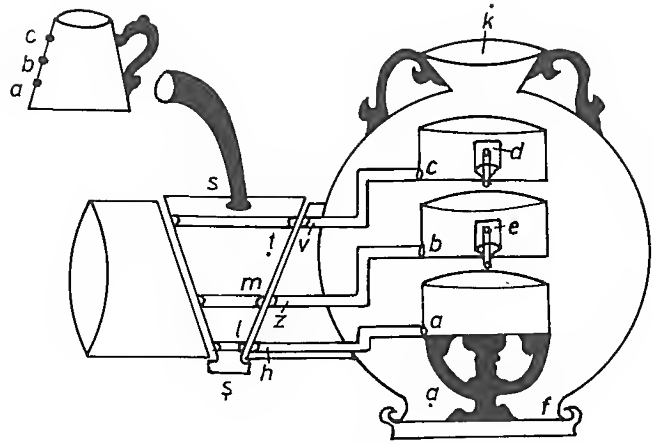


Figure 19-a (T)

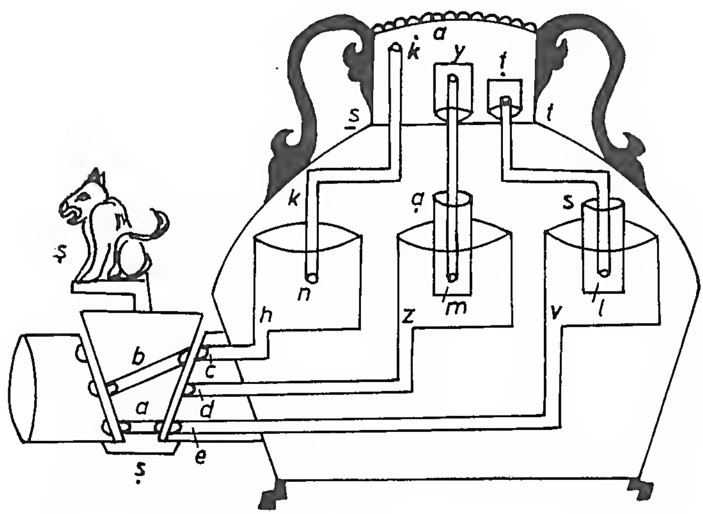


Figure 20-a (T)

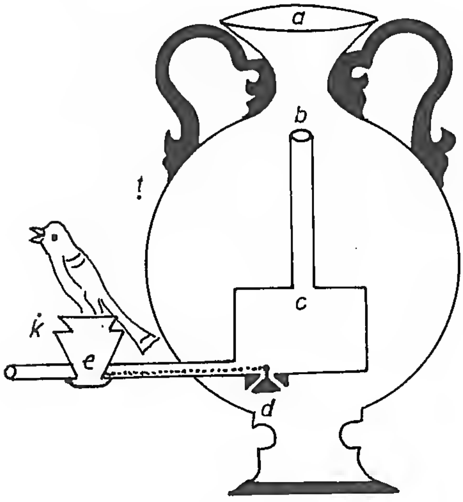


Figure 21-a (T)

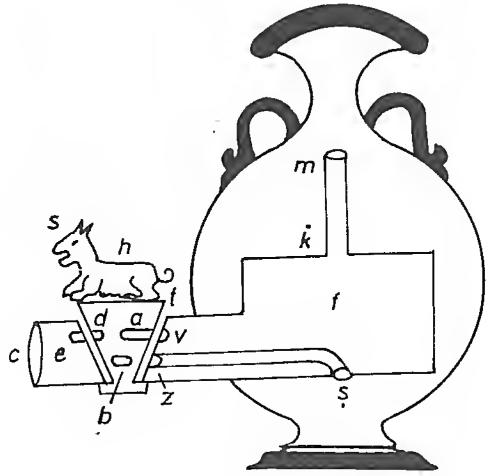


Figure 22-a (T)

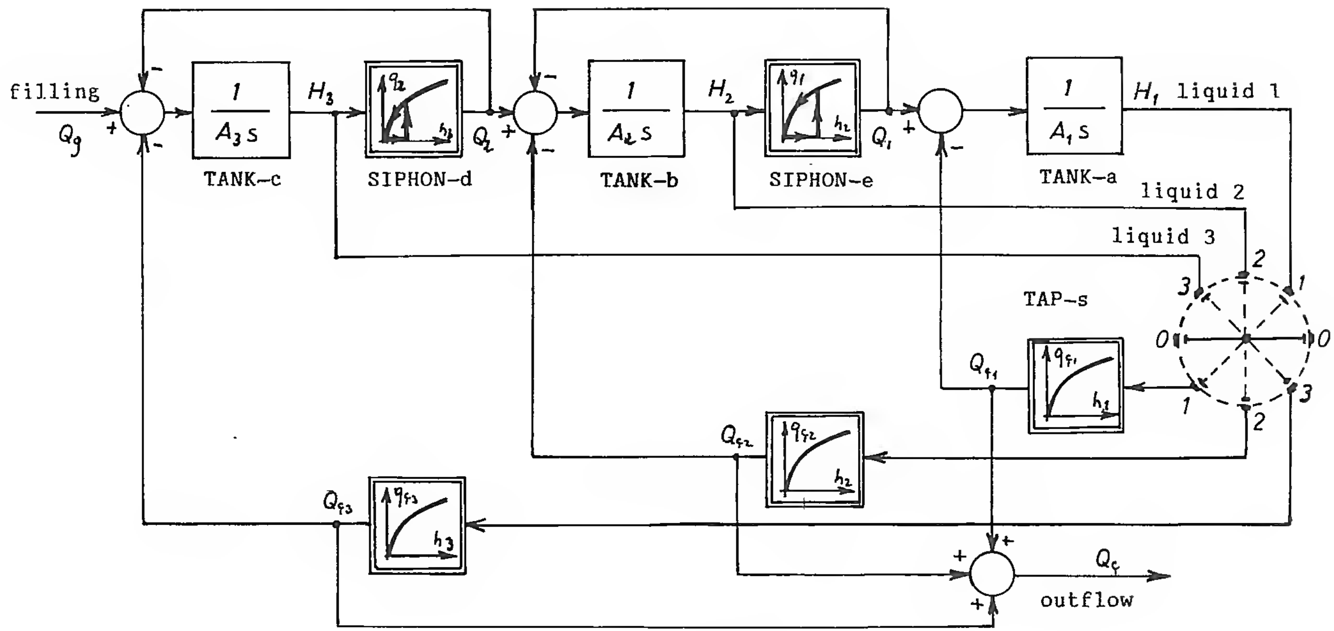

filling
Qg
1
A3 s
TANK–c
H3
SIPHON–d
Q2
1
A2 s
TANK–b
H2
SIPHON–e
Q1
1
A1 s
TANK–a
H1 liquid 1
liquid 2
liquid 3
TAP–s
Qf1
Qf2
Qf3
Qc
outflow

Figure 19–b

jar runs over the overflowing pipe **k̇-k-m** which is at the highest level and collects in the tank **h** because both of the double siphons are now plugged. After the pouring action is completed the user of the jar could extract the desired liquid by moving tap **ş** into the suitable position.

In Model 19, in order to collect different liquids in different tanks the amount of each liquid poured into the system is predetermined. In this model, the short intervals during the filling cause the separation procedure. In Model 19 the liquid tanks are connected in series but in this Model 20 they are parallely connected (Figure 20-b). The separation procedure of the liquids is realized by the "two double siphon + overflow" motif (see Motif 2)

Model 21-A Jar Which Pours Out A Determined Quantity of Liquid Each Time its Tap is Opened (Figure 21-a)

The water poured in collects in the jar. There is a small tank inside at the bottom of the jar. This inner tank is connected to the tap **k̇** with the pipe **e-d,** into the jar with the valve **d** and to the outside with the pipe **c-b.** There is a chain between the tap **k̇** and the valve **d.** When the tap **k̇** is closed the valve **d** opens and when it is open the valve closes. Let us assume that the tap **k̇** is closed. The liquid runs through the valve **d** which is open and fills the inner tank. The air in the tank goes out of the pipe **c-b.** When the tap **k̇** opens the valve **d** closes and the contents of the inner tank, a determined quantity of liquid, goes out through the pipe **e-k̇.** This procedure can be repeated until the liquid in the jar finishes.

The block diagram of the system can be seen in Figure 21-b. The amount of the liquid entering the inner tank is proportional to the difference of the liquids between the two tanks ($\Delta h = h_1 - h_2$). Since the height of the inner tank is retained low and the air pipe **c-b** is narrow, each time the tap is opened apporoximately the same amount of water runs out.

Model 22-Another Jar (see Model 21) Which Pours Out a Determined Quantity of Liquid Each Time its Tap is Opened (Figure 22-a)

The chain connected tap and valve combination used in Model 21 must

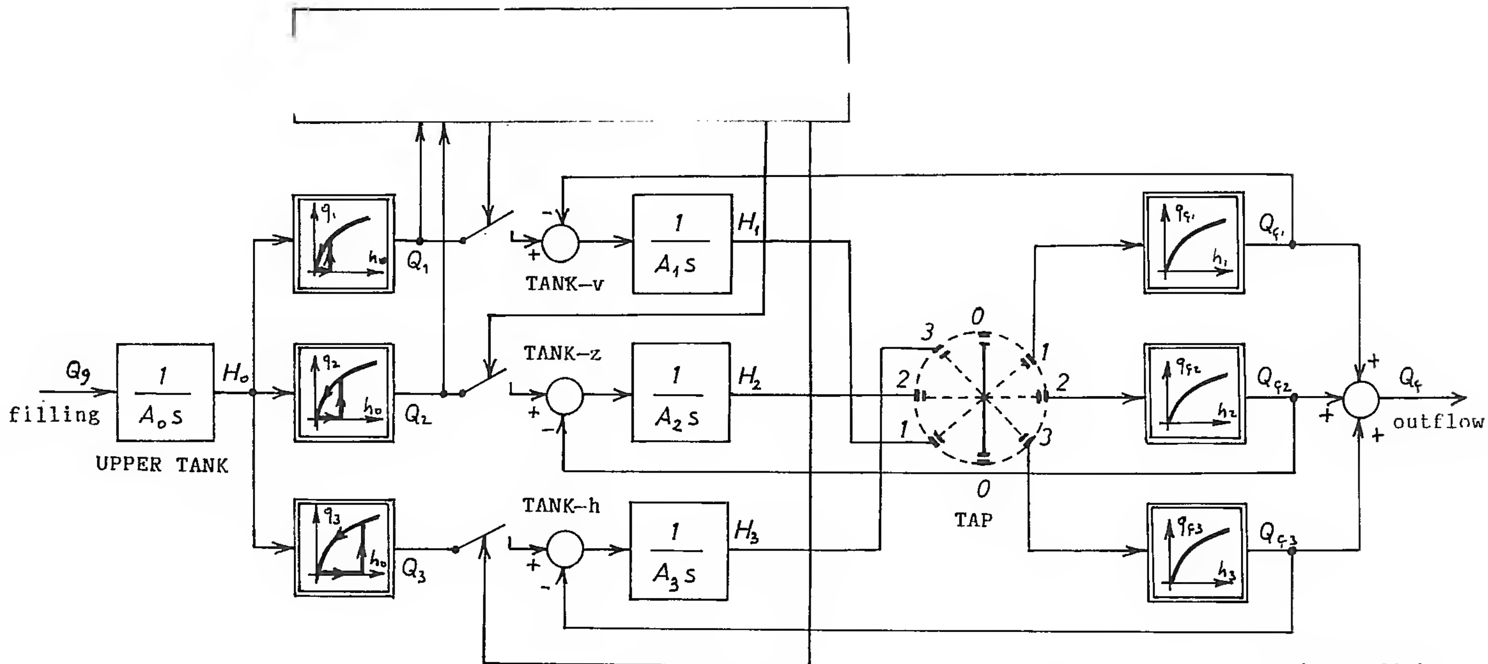


Figure 20-b

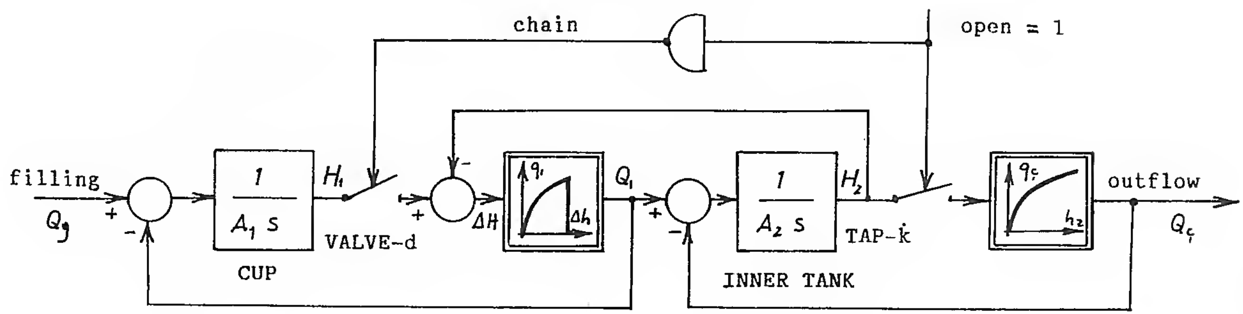


Figure 21-b

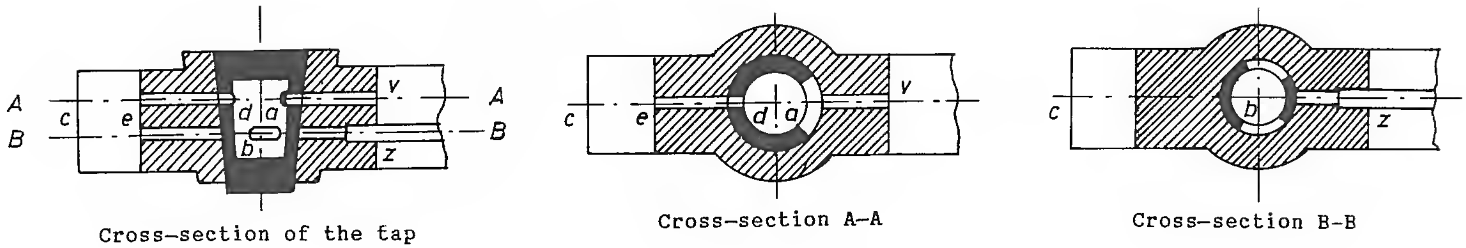


Figure 22-b

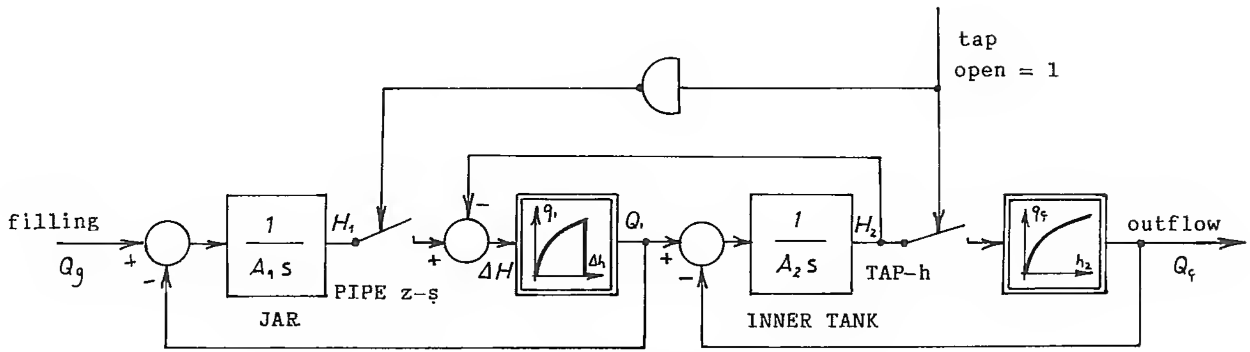


Figure 22-c

have shown its restrictions in application since here the same problem is realised with the help of a tap which have a special plug. At various cross sections the reconstruction of the tap plug is shown in Figure 22-b. When the tap is closed the pipe **ş-z-b** connects the inner tank with the jar body over the hole **v** of the tap plug. At this position, the level of the liquid in the inner tank reaches to the level of the liquid in the jar body. When the tap **h** is opened over the slots **v-a** and **d-e** of the tap plug, the determined quantity of liquid in the inner tank flows out through tap **e**.

This procedure can be repeated until the jar gets empty. The block diagrams of the system is given in Figure 22-c.

Model 23-A Goblet Which Gives the İmpression of Fullness or Emptiness to the Observer (Figure 23-a)

The goblet is covered with a sieve-like plate that has a sitting duck figure on the top. The poured liquid first goes through the sieve and flows into the upper partition **h-ţ**. The pipes **z-a** and **e-b** descend towards the bottom of the goblet until they almost touch it. If the hidden pipe **d-e-m** which secures the air entrance or outlet is closed by the user; the poured liquid cannot inflow or outflow from the goblet.

The block diagram of the system is given in Figure 23-b. In drinking parties the user of this goblet either drinks less or more than others, or lets other drink less or more than himself.

Model 24-A Jar That Gives Out Only the Second Liquid Which is Poured In When its Tap is Opened (Figure 24-a)

The jar covered with a sieve-like plate is divided verticaly in two parts by the middle partition **e-ạ-f**. The first poured liquid flows through the funnel like upper part, and the air obstacle **e-ţ** collects in the right side of the jar. The air in this partition goes out through the secret hole **z** placed at the handle of the jar. While pouring the second liquid, the user of the jar closes the hole **z** by his finger, and thus, the second liquid runs over the pipe **d-v-s** into the left part of the jar. The air in this partition goes out through the pipe **m-b**. When the tap **k̇** is opened,

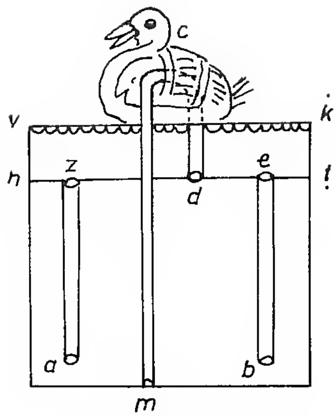


Figure 23–a (T)

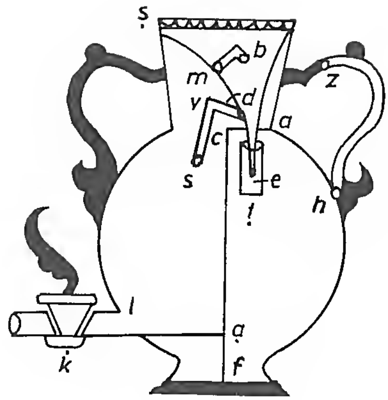


Figure 24–a (T)

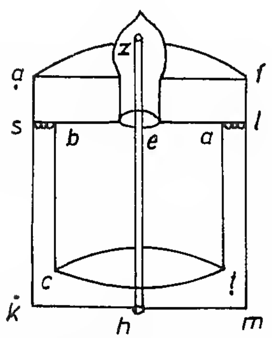


Figure 25–a (T)

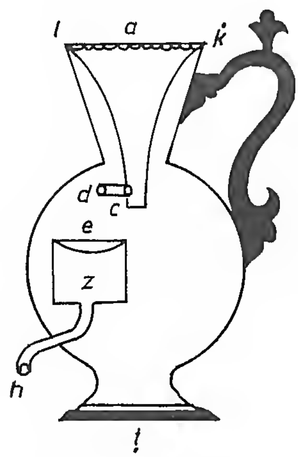


Figure 26–a (T)

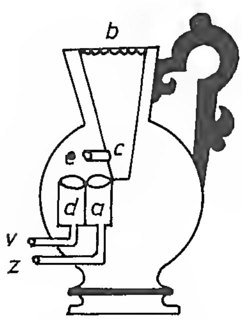


Figure 27–a (T)

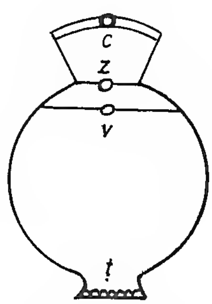


Figure 28–a (T)

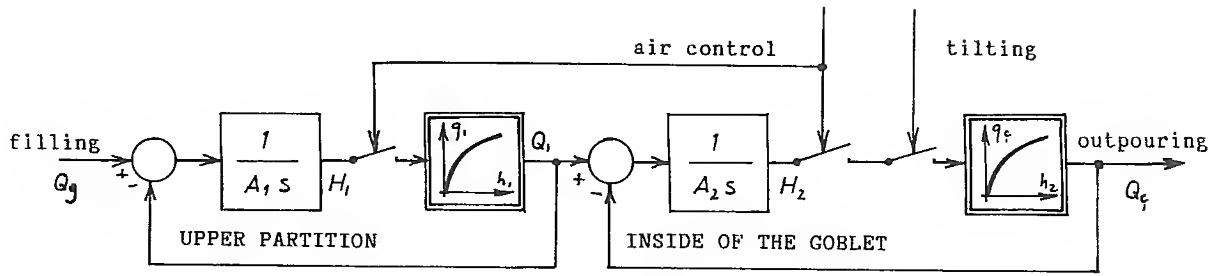


Figure 23–b

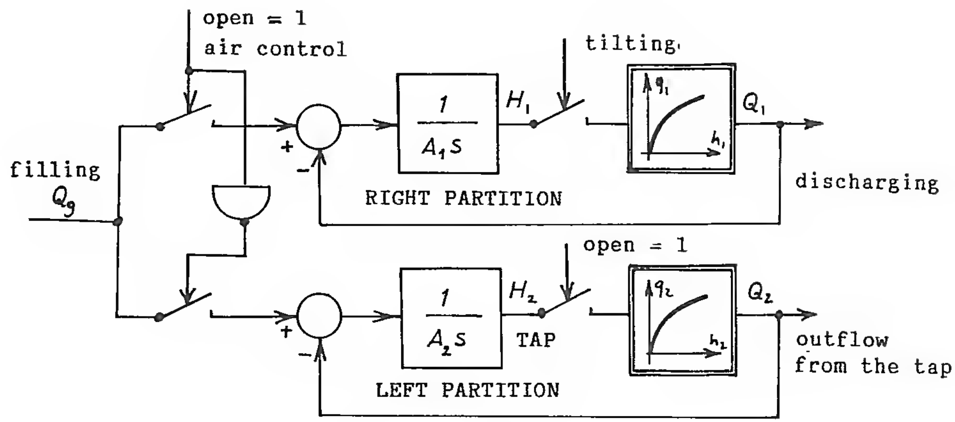


Figure 24–b

the second liquid which is stored in the left part flows out.
This jar could be used in drinking parties to play on tricks while serving. The user could control the quantity of the liquid running out of the open tap by controlling the hole **z**. Thus the user could pour out the desired amount of drink into the goblets. The block diagram of the system is given in Figure 24-b.

Model 25-Another Goblet (see Model 23) **Which Gives the Impression of Fullness or Emptiness to the Observer** (Figure 25-a)

The liquid which is poured into the goblet runs first into the upper partition and then flows through a sieve-like plate into the inner partition similar to the goblet explained in Model 23. During filling, the air in the inner partition goes out through the pipe **z-h** hidden under a lemon like figure in the middle of the goblet. If the user wants to give the impression of fullness or emptiness, he closes the hole **h** in the underside of the goblet with his finger. Another method of pouring less liquid from the goblet is to upturn the goblet violently so that the main part of the liquid stays in the inner partition. During this procedure the hole **h** can be left open. The block diagram of the system is given in Figure 25-b.

Model 26-A Jug Which Discharges or Not The Inpoured Liquid From the Outlet Pipe As Desired (Figure 26-a)

At the neck of the jug, which is covered with a sieve like plate, there is a funnel like partition. The end of the funnel being closed, a pipe **d-c** is solded to it. The tank **e-z** underneath this pipe is connected to the discharge pipe **h**. The user of the jug by controlling the flowrate of the inpoured liquid could obtain the liquid to discharge from the pipe **h** or not. If the liquid does not reach the tank **e-z**, it runs into the jug. In the block diagram given in Figure 26-b the model of the flowrate control motif is used (See Motif 3). The liquid collected in the jug is emptied by laying the jar.

Model 27-A Jug That the User Can Decide From Which Outlet the Inpoured Liquid Shall Flow Out (Figure 27-a)

The liquid which is poured into the jug through a perforated lid runs

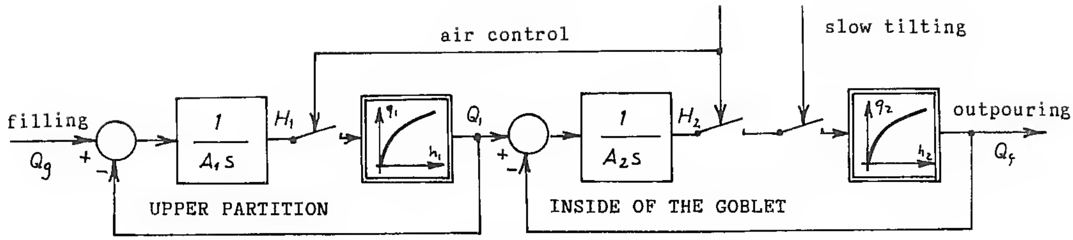


Figure 25-b

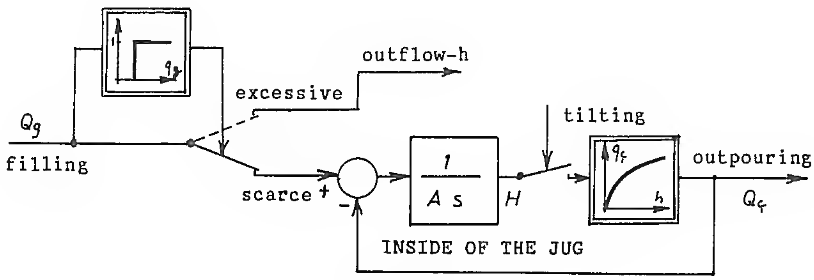


Figure 26-b

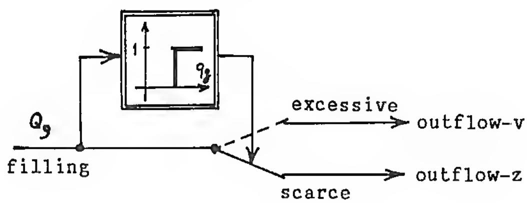


Figure 27-b

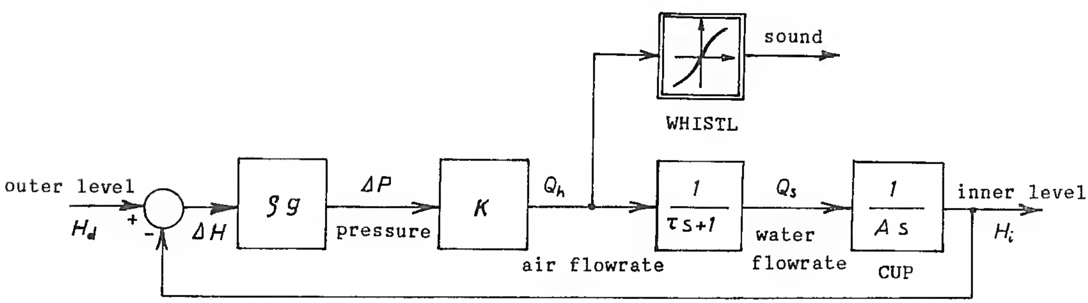


Figure 28-b

into a funnel-like partition which acts as a flowrate control mechanism (see Motif 3). If the flowrate of the inpoured liquid is scarce it discharges from the outlet **z** and if it is excessive it discharges from the outlet **v**. The block diagram of the system is seen in Figure 27-b.

Model 28-A Pipette Which Makes a Whistle When it is Immersed in or Taken Out of Water (Figure 28-a)

The pipette is immersed into the water by holding it from its neck. The difference of the water level h_d outside and h_i inside of the pipette $\triangle h = h_d - h_i$ forms the air pressure $\triangle p = \varrho g \triangle h$ in the pipette. This pressure causes the air flow through a hole **c** and the whistle **z-v**. The flowrate of the air is expressed as $q_n = k\triangle p$, **k** being a rate coefficient. The place emptied by the air is filled by the water from outside. Thus the water level h_i inside of the pipette rises. The whistling continues until the level difference $\triangle h$ is eliminated or the pipette has become full. In the same way if one takes the pipette out of the water the air taking the place of the water goes in the pipette through the hole **c** and the whistle **z-v**. The whistling continues as long as water exists in the pipette.

As it can be seen from the block diagram given in the Figure 28-b, this is a regulation system which continually tries to eliminate the level difference $\triangle h$. In the model, a first order time delay with time constant τ is used between the air flowrate q_h and the water flowrate q_s. The water flowrate q_s and the water level h_i obey the law $q_s = A\, dh_i/dt$; **A** being the medium cross section of the pipette. The whistling depends on the presence of the air flow. This is expressed with a nonlinear block in the model.

Model 29-A Pipette That When Immersed in Water the Entering, and When Taken Out of Water, the Outpouring Water, Can Be Regulated (Figure 29-a)

The bottom of the pipette is covered with a sieve like plate. When the pipette is immersed in the water, the level of the water in the pipette rises till it reaches the water level on the outside. The air in the pipette goes out through the air obstacle (see Motif 7). If the user wants the

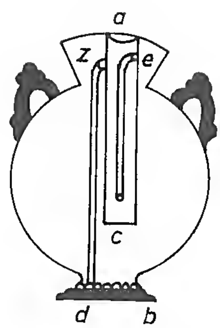


Figure 29-a (T)

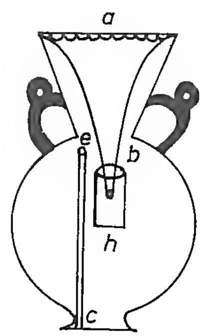


Figure 30-a (T)

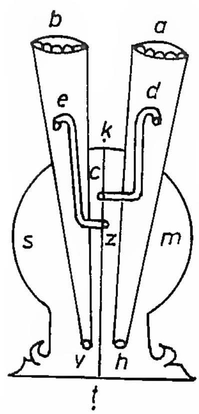


Figure 31-a (T)

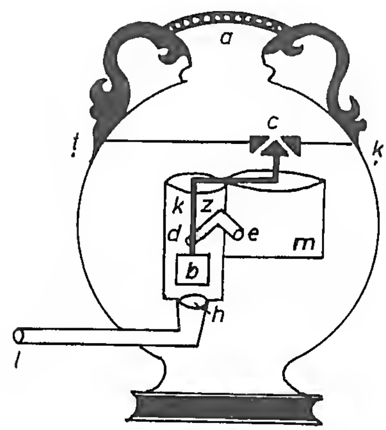


Figure 32-a (T)

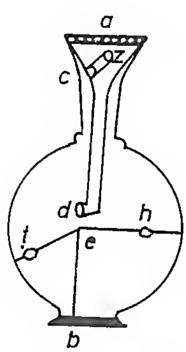


Figure 33-a (T)

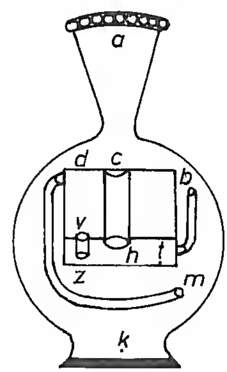


Figure 34-a (T)

pipette to stay empty he immerses it quickly to the level **z**. The water rising instantly in the pipe **d-z** enters in the pipe **e-c.** Then even though the pipette is immersed in the water for a long time it can not be filled.

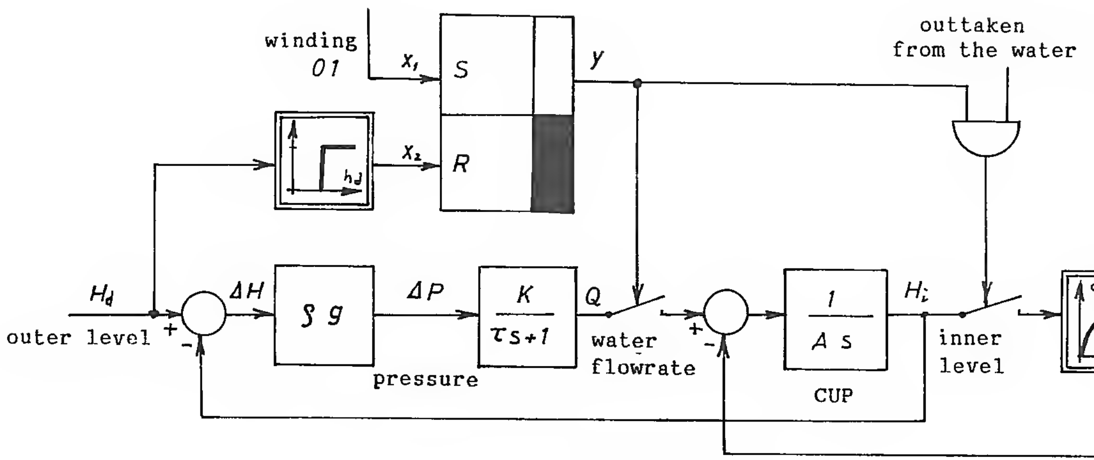
If the user immerses the pipette such that the water does not reach the level **z** and then takes it out, the pipette empties again. If the user does not want to let the water run out of the full pipette after taking it out of the water, then he has to immerse it down to the level **z** just before taking it out. Thus, the water entering the pipe **a-c** prevents the air from entering in the pipette through the pipe **e-c** and the pipette can be taken out of the water full.

The block diagram of the system is given in Figure 29-b. The dynamic behaviour of the system is equivalent to the Model 28. Only the mechanism which regulates the pipette to stay empty or full is equivalent to a S-R memory element. As can be seen from the truth table after the system is set up ($x_1=1$), one can fill the pipette with water or take it out full with water ($y=0$) only if the water level h_d on the outside reaches the level **z** in the pipette ($x_2=1$). The system comes to its first position again only if the **a-c** pipe is emptied or the set up signal $x_1=1$ is given.

Model 30-Another Flask (see Models 23 and 25) **Which Gives the Impression of Fullness or Emptiness to the Observer** (Figure 30-a)

The top of the flask is covered with a sieve-like plate. The poured liquid first flows into the funnel-like upper partition and from here pours into the flask passing through the air obstacle **b-h** (see Motif 7). The air inside the flask goes out from the pipe **e-c.** If the user of the flask wants to stop the flow of the liquid into the flask, he closes the end **c** of the pipe **e-c** either by his finger or by a piece of wax. In the same way it is also possible to prevent the outpouring of the liquid from the flask by closing the air entrance **c.**

The block diagram of the system can be seen in Figure 30-b.



x_1	x_2	y
0	1	0
1	0	1
1	1	0
1	0	0

Figure 29-b

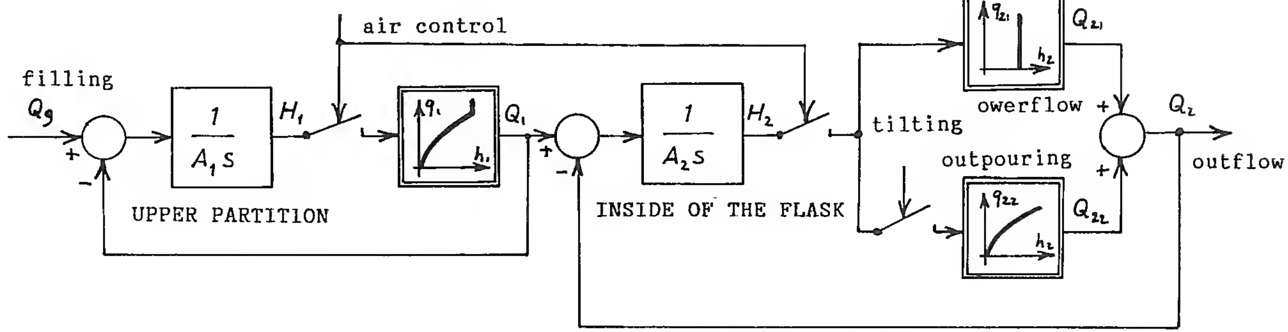


Figure 30-b

Model 31-A Flask With Two Heads, in Which Different Kinds of Liquids Are Poured, When the Flask is Tilted the Liquids Flow Out Unmixed, but Having Changed Heads (Figure 31-a)

The liquid which is poured in from the right head **a** of the flask runs through the funnel like extension **h** into the right side partition of the flask. The air of this partition goes out through the pipe **z-e**. Another liquid which is poured in from the left head **b** of the flask runs through the extension **v** of the left side partition, and the air of this partition goes out through the pipe **c-d**. When the flask is tilted for outpouring, the liquid in the right side partition flows out through the left head **b** following the track **z-e-b** and the liquid in the left side partition pours out from the right head **a** following the track **c-d-a**. The air enters the flask through the funnels **a-h** and **b-v.**

In the block diagram of the system (see Figure 31-b) the tracks which the liquids follow when the flask is tilted are expressed by crossing of the outflow signals.

Model 32-A Jar Which Pours Out Liquid in Certain Quantities and Predetermined Intervals Until All its Content is Evacuated (Figure 32-a)

The jar is divided in two sections with the partition **ṭ-ḳ**. The liquid which is poured in through the spout covered by a sieve-like plate, collects at the upper section of the jar. Some of the liquid flows through the valve **c** into the tank **m**. When in this tank the level of the liquid reaches **z**, the siphon **e-z-d** suddenly transmits the liquid to the tank **k-z** which contains a float in it. The float **b** of this tank rises and closes the valve **c**. The contents of the tank **k-z** pours out through the pipe **h-l**. The float **b** sinks along with the level of the liquid in the tank **k-z** and the valve **c** connected to this opens. This operation continues until the liquid in the upper section is exhausted.

In the sense of modern system engineering this system is equivalent to an oscillator. As seen from the block and time diagrams given in Figure 32-b this is the first realization of a periodical wave generator.

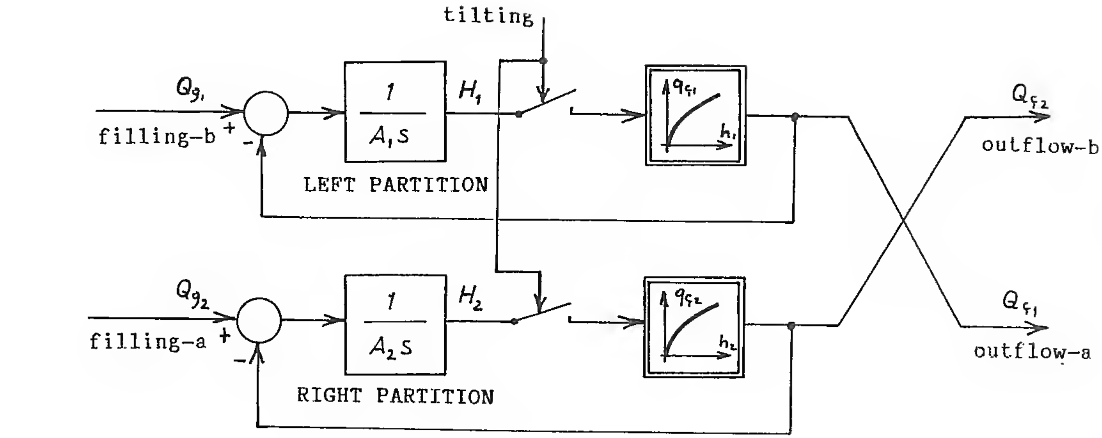


Figure 3I-b

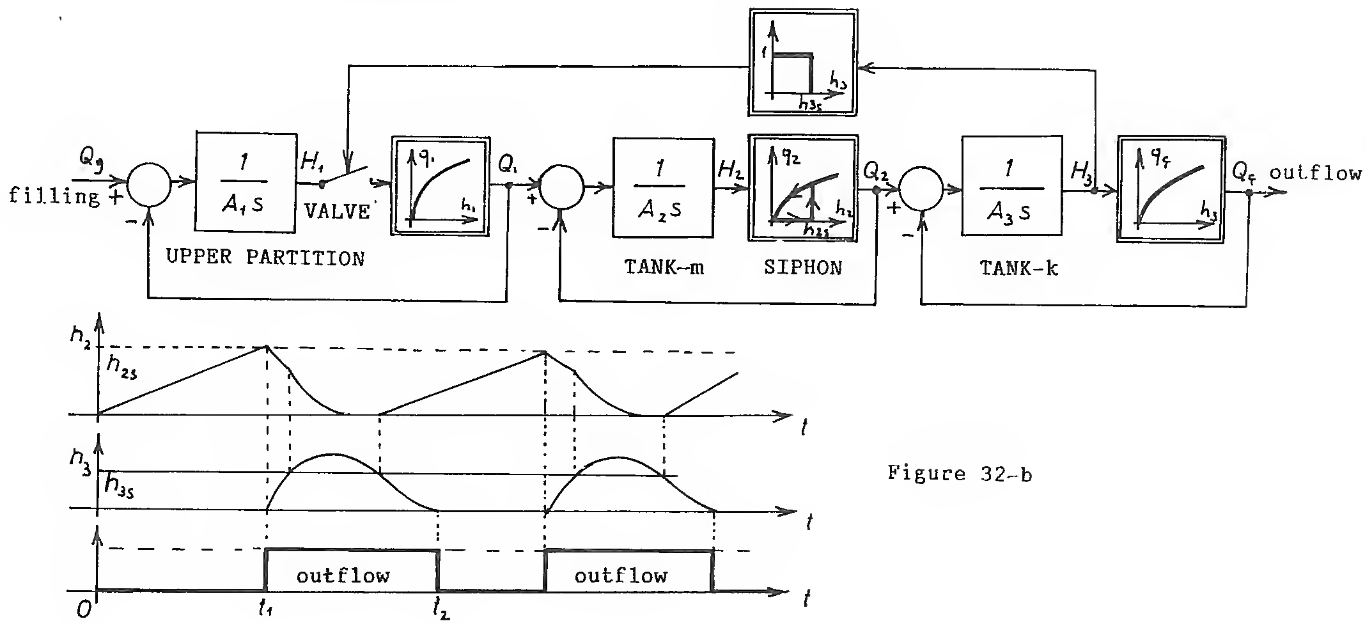


Figure 32-b

Model 33-A Flask Which Pours Out As Desired Water, Wine or the Mixture of Both (Figure 33-a)

The flask is covered with a sieve-like plate. When the liquid is poured in the flask gently it gathers within the right and if it is poured forcefully it gathers within the left partition (see Motif 3). During filling, the air from the partitions goes out through the pipe **c-z.** (In the figure the lid **e-h** has been erroneously drawn vertically; in order to prevent the liquids mixing must have been inclined towards the right as the lid **e-ţ** is drawn inclined to the left.)

The user while filling a goblet tilts the flask to the right, to the left or to the middle according to his aim. Thus water, wine or the mixture of them flows from the holes **ţ** and **h** and runs out from the pipe **c-z.** During outpouring, the air enters into the flask through the pipe **a-d.**

The block diagram of the system is given in Figure 33-b. The outpouring amount of the liquids, proportional to the tilting direction, are expressed in the block diagram by variable coefficients.

Model 34-A Flask That Pours Out A Certain Quantity of Wine Each Time It is Tilted (Figure 34-a)

The flask which's top is covered with a sieve like plate contains an inner tank divided in two parts. The wine that is poured in the flask first runs through the hole **c** which is on the lid of the tank **d-c-b** and flows through the pipe **c-h** into the tank (in the text it is pointed out that the lid **d-c-b** of the tank is slanting down towards the hole **c** in order to prevent the scattering around of the liquid which is poured into the flask; also in the figure the pipe **c-h** is shown extending to the tank **ţ**, but correctly it must end at the base of the tank **v**). The wine in the larger tank **v** running through the pipe **z-v** fils also the small tank **ţ.** The air goes out through the pipes **ţ-b** and **d-m.** When it is desired to pour out wine the flask is tilted towards right and the determined quantity of wine which is in tank **h** flows out through the pipe **ţ-b.** During this action the air enters into the lower tank through the pipes **m-d** and **v-z.** When the flask is put down in its normal position the

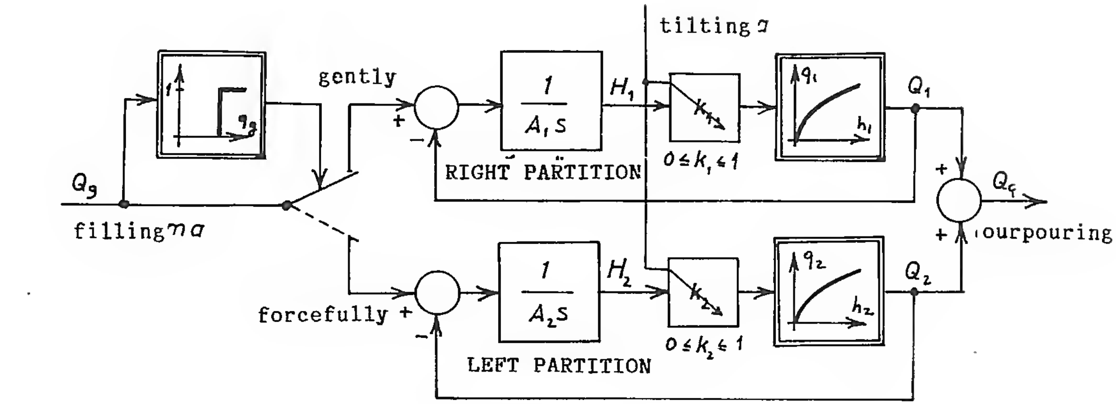


Figure 33-b)

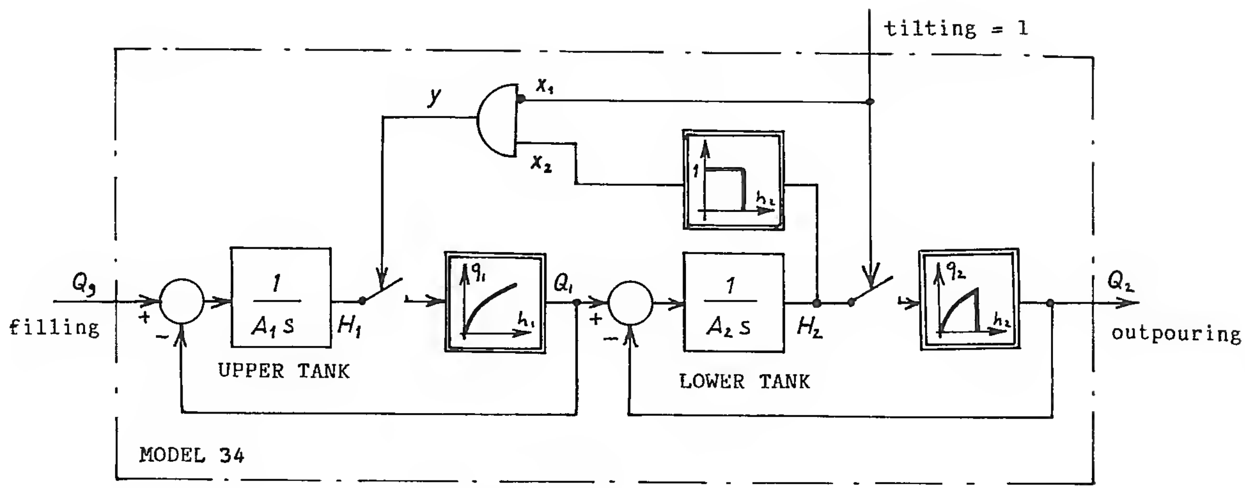


Figure 34-b

wine in the upper tank **v**, refills the lower tank **ţ** through the pipe **v-z**. Thus, until the contents are exhausted, each time the flask is tilted only a predetermined quantity of wine pours out.

The block diagram of the system is given in Figure 34-b. In order to pour the wine from the upper tank into the lower ($y=1$) the flask has to be in the upward position ($x_1=0$) and the lower tank has to be empty ($x_2=1$).

Model 35-A Flask That Does Not Pour Out at the First Tilting but Pours Out Wine at the Second Tilting and Behaves Consequently Thereafter (Figure 35-a)

Inside this flask, additional to the system 39, there is another tank **d** (see Model 34). When the flask is tilted the wine which is in the lower small tank **ţ** pours through the pipe **ţ-b** into the tank **d** (the pipe **ţ-b** has to be extended upward in tank **d**, otherwise the wine would pour back in the tank **ţ** when the flask is put upright). When the flask is upturned the wine pouring through the pipe **v-z** refills the small tank **ţ**. At the second time the flask is tilted the level of the wine in tank **d** reaches the level **ş** and the siphon **ş-f** takes all the wine of the tank **d** and pours it out. This procedure can be repeated until all of the wine in the tank **v** is exhausted. If it is desired that the flask pour out when it is tilted for the **n**' th time and behave consequently thereafter, the volume of the tank **d** has to be **n** times the volume of the tank **ţ**.

The block diagram of the system is given in figure 35-b.

Model 36-A Flask That When Tilted Pours Out Nothing, Less or Much Wine As Desired (Figure 36-a)

In this flask again the tanks of systems 34 and 35 are present (see Models 34 and 35). When the flask is tilted the wine of the tank **z** starts running from the pipe **z-b** (the **b** end of the pipe has to be turned towards right). If the user tilts the flash slightly left, all of the wine flows out. If he tilts it towards the middle, or slightly to the right, some or all of the wine flows from the **b** end of the pipe into the tank **e** which is beneath it. As the liquid runs from the pipe **r-l** into the tank **e** the air goes out through the pipe **r-s**.

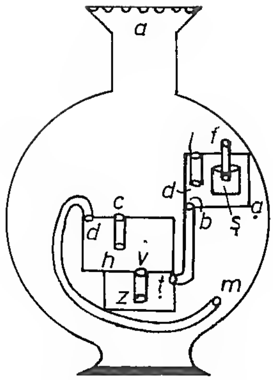


Figure 35—a (T)

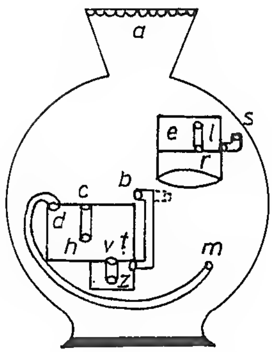


Figure 36—a (T)

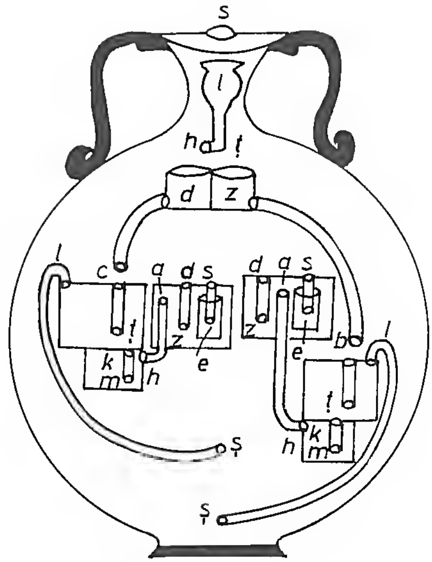


Figure 37—a (T)

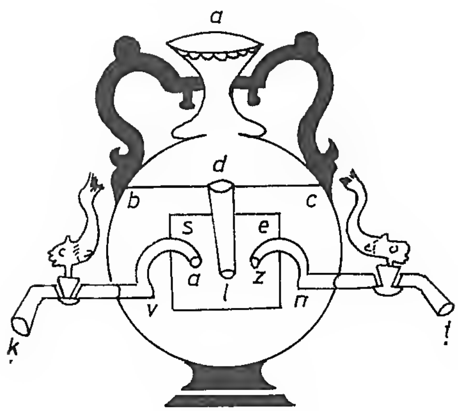


Figure 38—a (T)

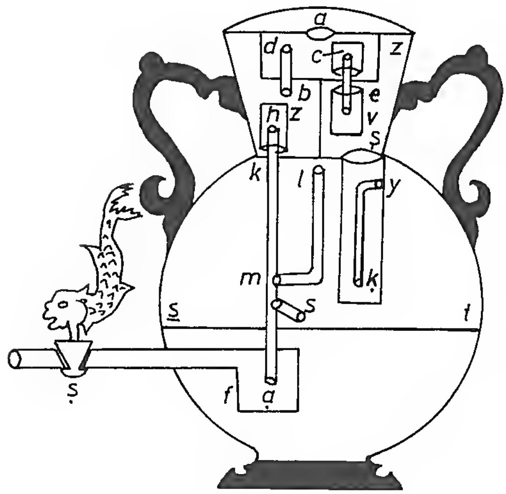


Figure 39—a (T)

The block diagram of the system is given in Figure 36-b. The amount of the wine that flows into the tank **e**, which is proportional to the tilting direction, is expressed in the block diagram by a variable coefficient.

Model 37-A Flask Which Pours Out a Predetermined Quantity of Water at the First Tilting and a Predetermined Quantity of Wine at the Second; and Behave Consequently Hereafter
(Figure 37-a)

First, the wine is forcefully poured into the flask from the hole **s**. The wine runs through the funnel **l-h** into the container **d** and from there flows over the pipe **d-c** into the left tank **ţ**. From there, the wine also flows over the pipe **k-m** into the tank **m** and enters tank **z** over the pipe **h-a**. During the filling the air in the tanks goes out from pipes **l-ş** and **e-s**. When the filling of the wine ends the whole of the tanks **ţ** and **m** on the left are completely full of wine and the tank **z** is full, nearly close to the level **a** (half of the tank **z**).

Secondly, the water is gently poured in from the hole s of the flask. The water runs through the funnel **l-h** into the container **z** and from there going over the pipe **z-b** flows into the right tank **ţ**. While the tanks **ţ** and **m** are being filled with water, the air goes out from the pipes **l-ş** and **k-a-z-d**. The tank **a** on the right remains empty because its level is higher than **ţ**.

As seen, in this system the model 35 has been applied twice. Only, by taking the level of the tank **z** on the left side to the level of the tank **ţ**, it is ensured that the wine is the first liquid to pour out when the flask is tilted. At the beginning the halfway full tank **z** fills up with the wine that flows from the tank **m**. At the first tilting the whole content of the left side tank **z** pours out flowing through the siphon **e-s**. At the same moment the water from right side tank **m** pouring through pipe **h-a** flows in the right side tank **z**, and fills it halfway.

If the flask is tipped back, put down and tilted again, the water from the right tank **m** is running over the pipe **h-a** in the right tank **z**. When the level of the water reaches the upper end **e** of the siphon **e-s**, all the

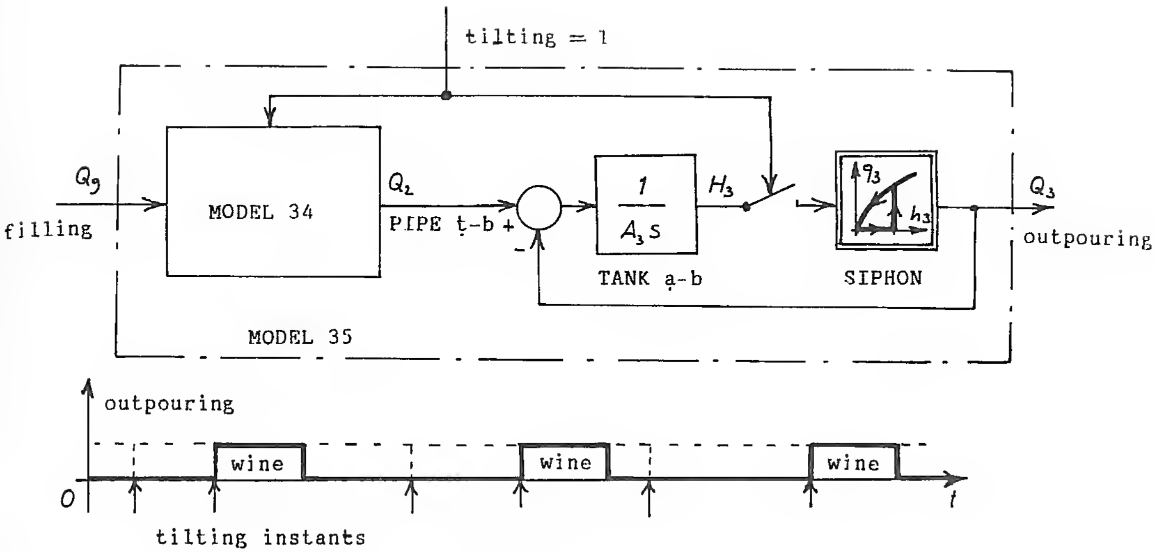


Figure 35-b

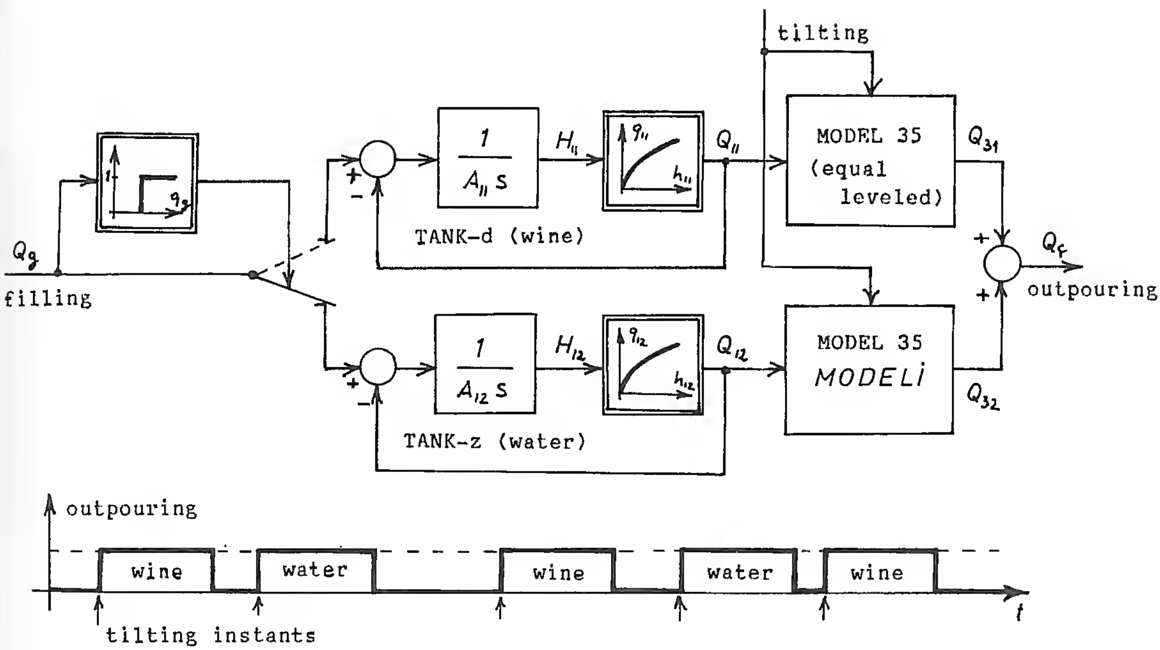


Figure 37-b

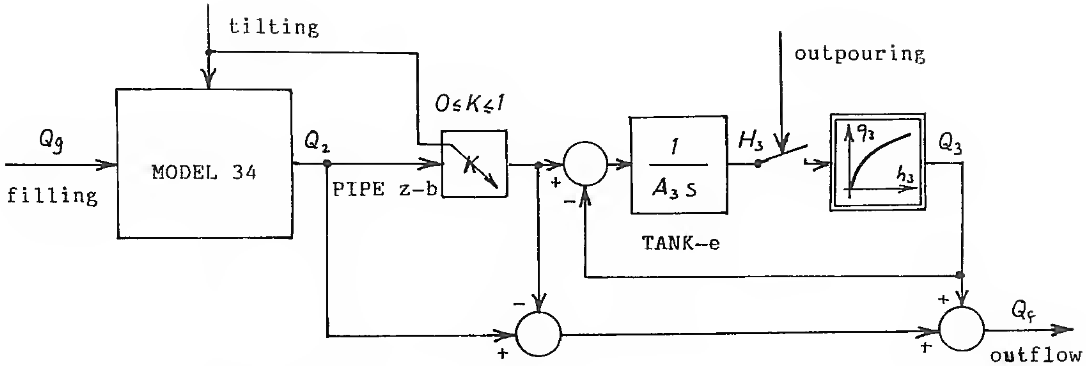


Figure 36-b)

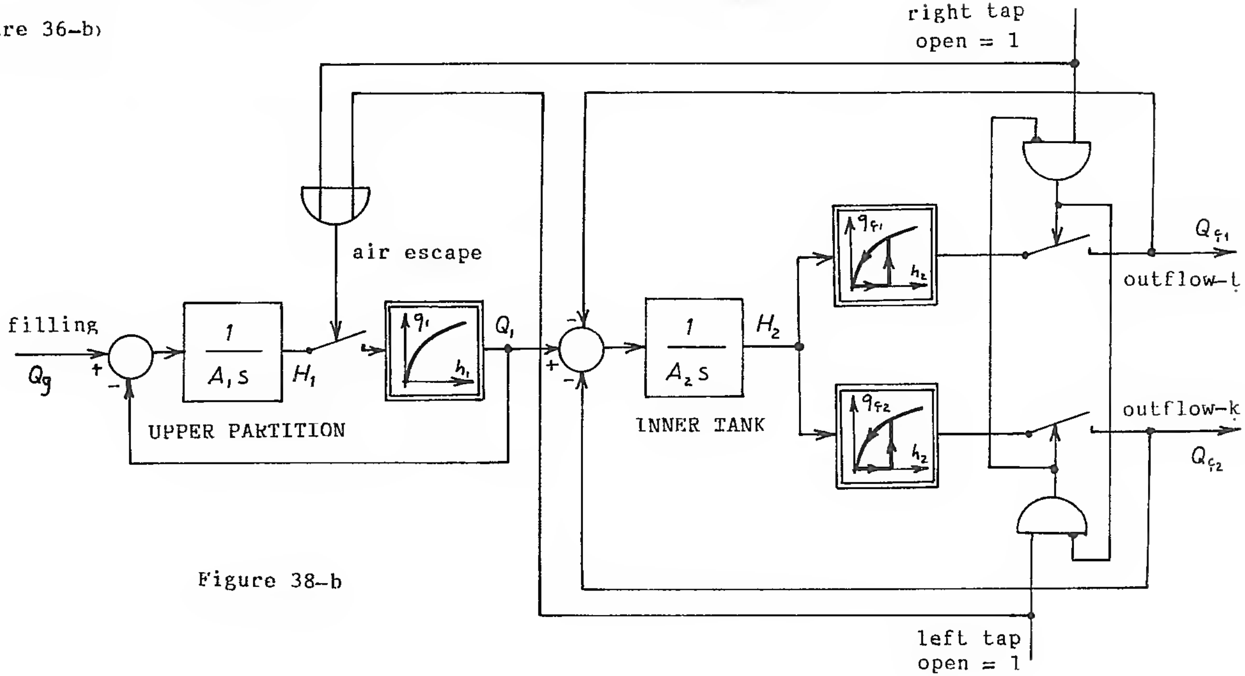


Figure 38-b

water contained in the right side tank **z** pours out. At the same time the wine running from the left tank **m** into the left tank **z** fills this tank halfway. When the flask is retilted, wine now flows out; and so on water and wine pour out alternately until the contents of the flask are exhausted.

The block diagram of the system is seen in Figure 37-b. The left one of the two models 35 applied in this system is named "equal levelled" since the tank **z** is at the same level as the tank **ţ**.

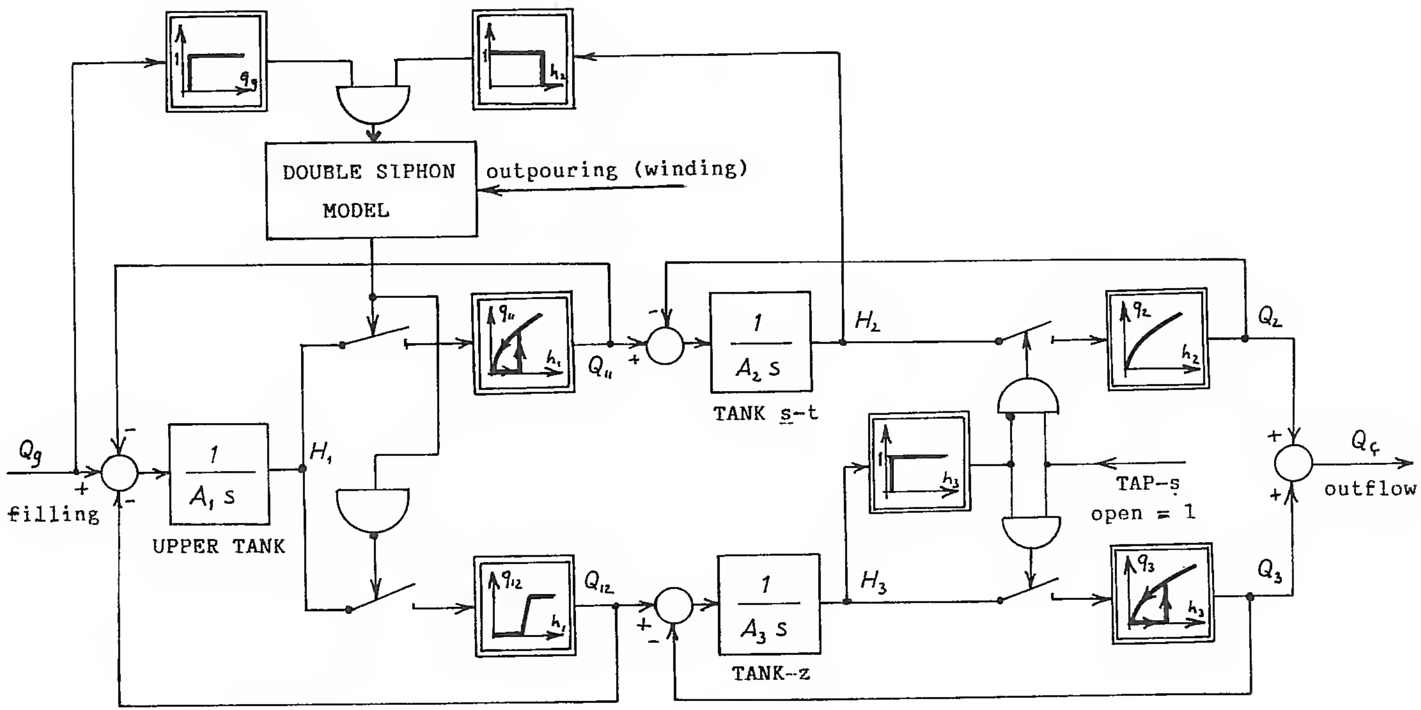
Model 38-A Jar With Two Taps Which Pours Out the Containing Liquid Always from the First Turned on Tap (Figure 38-a)

The liquid poured in the jar collects within the upper partition formed by the plate **b-c**. The pipe **d-l** connects the upper partition to the inner tank. The liquid does not flow in the inner tank as long as the taps **ķ** and **ţ** are closed since the air cannot escape from it. As soon as one of the **ķ** or **ţ** taps is turned on the liquid precipitates in the inner tank and runs out flowing through the siphon-like pipe of the open tap. If one turns on the closed second tap nothing flows out because the level of the liquid in the inner tank does not reach the upper level of the second tap's siphon-like pipe. As pointed in the book this condition can only be realised if the cross-section of the pipe **d-l** is smaller than the cross sections of the siphon-like pipes **a-s-v** and **z-e-n**.

In the block diagram of this system (see Figure 38-b) matters such as air escape from the inner tank, and the fact that the two siphons cannot be transitive simultaneously, are modelled by logic elements.

Model 39-A Jar Filled With Wine, Each Time When Water is Poured In, or the Filling Ends and the Tap is Turned on, It First Pours Out the Last Inpoured Water (Figure 39-a)

The wine, which is poured continuously in the jar from the hole **a** flows through the double siphon **c-v-e** and the air obstacle **ş-ķ-y** into the tank **ș-t**. From here only a little amount of wine just enough to cover the end **ạ** can pass through the pipe **s-ạ** into the tank **f**. During filling the air of the tank **s̱-t** goes out following the way **l-m-h-k-b-d-a**. After the



DOUBLE SIPHON MODEL
outpouring (winding)
Q_g
filling
+
-
1
A_1 s
UPPER TANK
H_1
q_{11}
h_1
Q_{11}
q_{12}
Q_{12}
q_g
h_2
A_2 s
TANK s-t
H_2
q_2
Q_2
A_3 s
TANK--z
H_3
h_3
q_3
Q_3
TAP--s
open = 1
Q_f
outflow

Figure 39-b

filling ends, if the tap **ş** is turned on, the wine flows out following the pipes **s-ạ-f-ş**, and the air refills the tank **s̱-t** from the same way as it has gone out.

The water which is poured secondly into the jar from the hole **a**, flows through the overflow pipe **d-b** in the tank **z**, because the double siphon does not accept a second pass. When the tap **ş** is turned on, first the water goes out flowing through the siphon **k-h** and the pipe **k-m-ạ-ş**. Only after all the water inside the tank **z** has run out the air re-enters into the tank **s̱-t** through the pipe **m-l** and the wine inside this tank starts to flow out through the way **s-m-ạ-ş**.

The block diagram of the system is given in Figure 39-b. In this system the procedure of gathering the wine in a separate tank is realised with a double siphon (see Motif 2). The outflow priority given to the water which is poured secondly in the jar is realised by the air control (see Motif 7). In the block diagram these functions are modelled with logical elements.

Model 40-Another Jar (see Model 39) **Which is First Filled With Wine; When its Tap is Turned on and Water is Also Poured In, it First Pours Out the Just Filled Water** (Figure 40-a)

The wine is first poured into the jar through the hole **ţ**. The wine in the upper tank after filling the tube **t-z** and reaching the level **l** of the siphon **a-l**, flows into the jar following the track **a-l-b-ạ-k**. Due to the difference in the air pressures the air in the jar passes through the wine obstacle in the tube **z-t** in form of air bubbles and goes out following the pipe **d-e-z**. When the filling ends, the wine in the upper tank **ţ-ş-t** is transferred by the siphon **a-l** into the jar, till it reaches the level **ş-t**. When the tap **ķ** is turned on the wine inside the jar runs out through the pipe **k-ạ-ķ**. The air enters into the jar following the track **ţ-a-l-b-e**. If water is also poured in the jar, while the tap **ķ** is turned on, this water flowing through the siphon **a-l** and the tap **ķ**, plugs the air entrance into the jar, thus blocks the out pouring of the wine through the pipe **k-ạ**. After all of the water poured into the jar runs out, the normal outpouring of the wine continues.

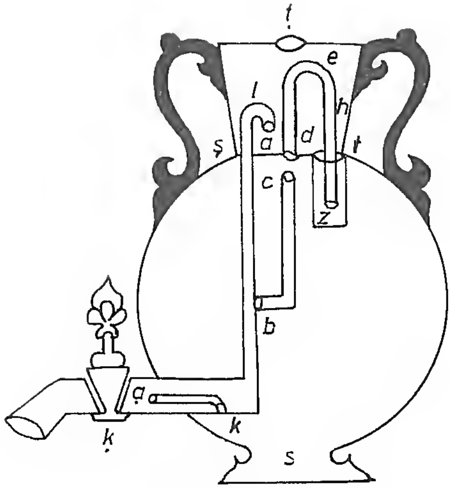


Figure 40—a (T)

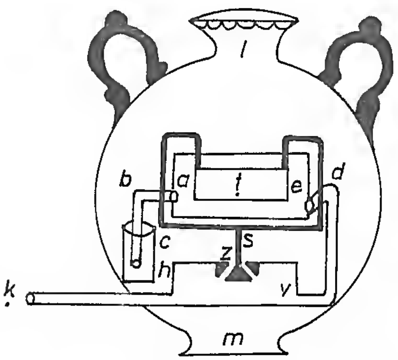


Figure 41—a (T)

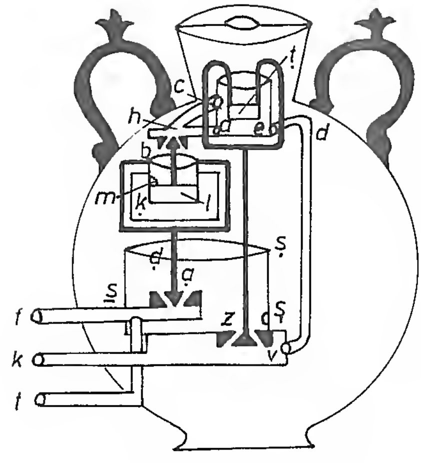


Figure 42—a (T)

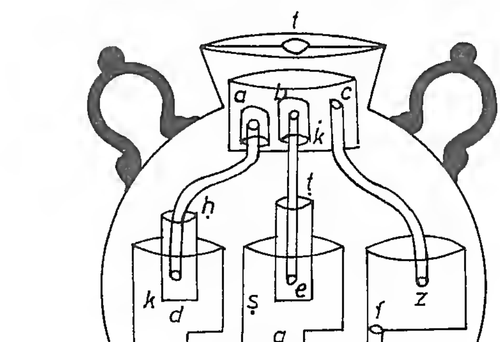


Figure 43—a (T)

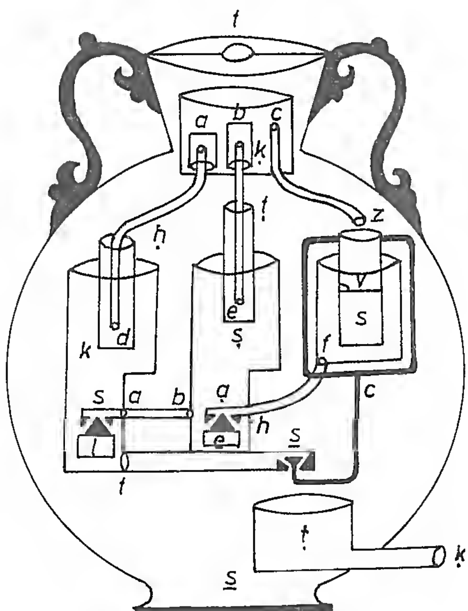
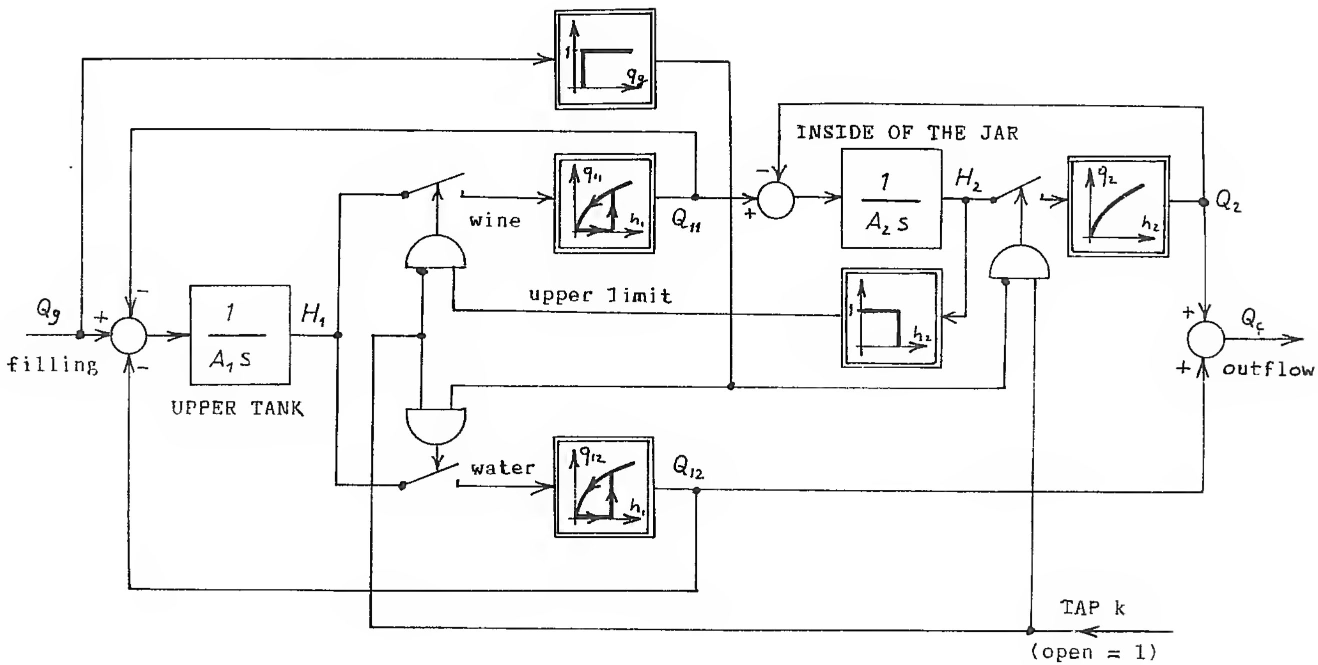


Figure 44—a (T)



INSIDE OF THE JAR
1
A2 S
H2
Q2
Q11
wine
upper limit
Qg
filling
1
A1 S
H1
UPPER TANK
water
Q12
Qc
outflow
TAP k
(open = 1)

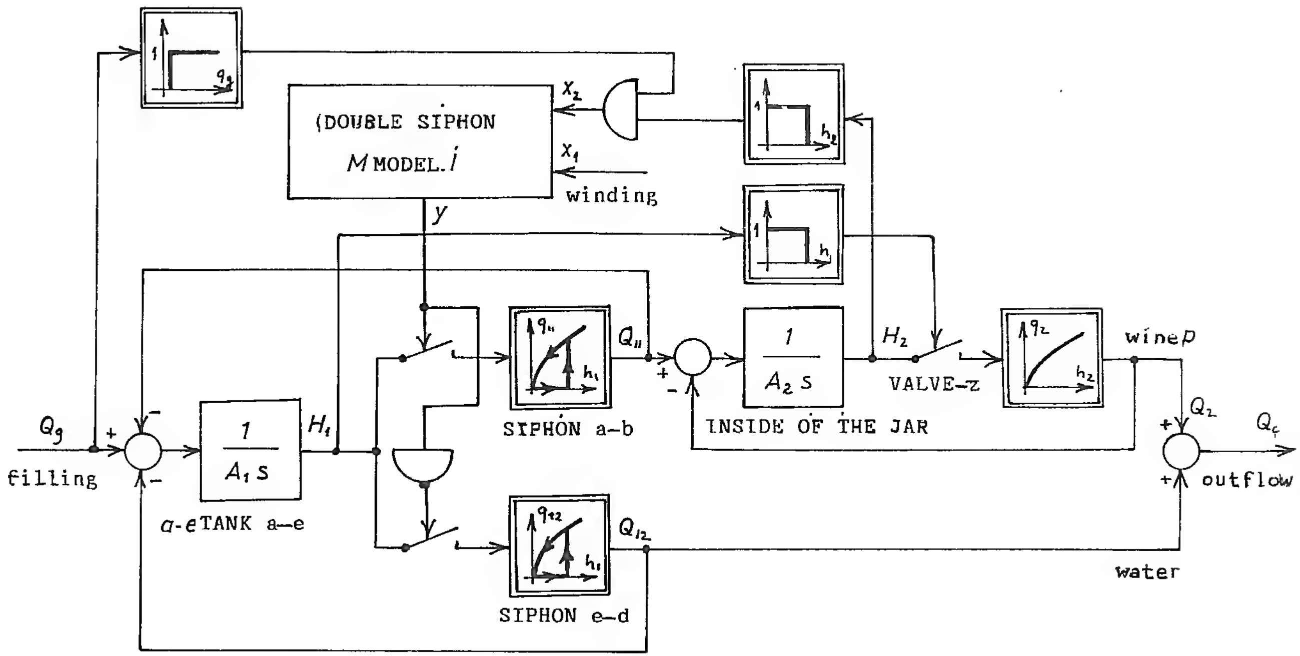
Figure 40-b

The block diagram of the system is given in the Figure 40-b. In the model various functions are realized by switches controlled by logical elements. In order to have wine collected in the jar, the jar has to be empty and the tap has to be turned off. And, to pour out water from the jar, it has to be poured in and the tap has to be turned on. At last to pour out the wine from the jar the filling has to be ended and the tap has to be turned on.

Model 41-A Jar With a Free Outflow Which Pours out As Soon As the Filling of the Wine Ends; and When Also Water is Poured In, It First Discharges the Last Inpoured Water (Figure 41-a)

The wine is continously poured in the jar through a sieve like plate flow in the tank **a-e** that contains a float with a closing valve (see Motif 4). As the level of the wine rises in the tank, the float rises and closes the valve **z** that is tied to it. When the level in the tank reaches **b** the wine flows through the double siphon **a-b-c** in the jar (in the Figure the end **a** of the double siphon is erroneously drawn at the **b** level). When the filling ends, the double siphon **a-b-c** transfers all the wine from the tank **a-e** in the jar, the level of the float **ṭ** decreases, and by the opening of the valve **z** the wine in the cup starts to discharge from the pipe **z-ḳ**. If water is poured into the jar, it raises the float **ṭ** in the tank **a-e** and the valve **z** recloses. Now, since the double siphon **a-b-c** is obstructed the water poured into the tank **a-e** flows through the siphon **e-d-v** which has a higher level **d** than **b**. Thus, the water following the track **e-d-v-ḳ** begins to discharge. When the inpouring of the water ends, the siphon **e-d-v** empties the tank **a-e**, the float **ṭ** decreases, the valve **z** reopens and the wine starts to re-discharge from the pipe **ḳ**.

In the block diagram given in Figure 41-b, having wound up ($x_1=1$) the double siphon model (see Motif 2), the pouring of the water into the jar ($y=1$) depends on the emptiness of the jar and on the continuity of the inpouring ($x_2=1$). After the first interruption ($y=0$) the liquids flow out directly over the siphon **e-d**. The outpouring of the wine i.e., the open position of valve **z** depends on the emptiness of the tank **a-e** (h_1 level is insignificant).



(DOUBLE SIPHON
M MODEL. i
winding
SIPHON a–b
INSIDE OF THE JAR
VALVE–z
wine p
outflow
filling
a-e TANK a–e
SIPHON e–d
water

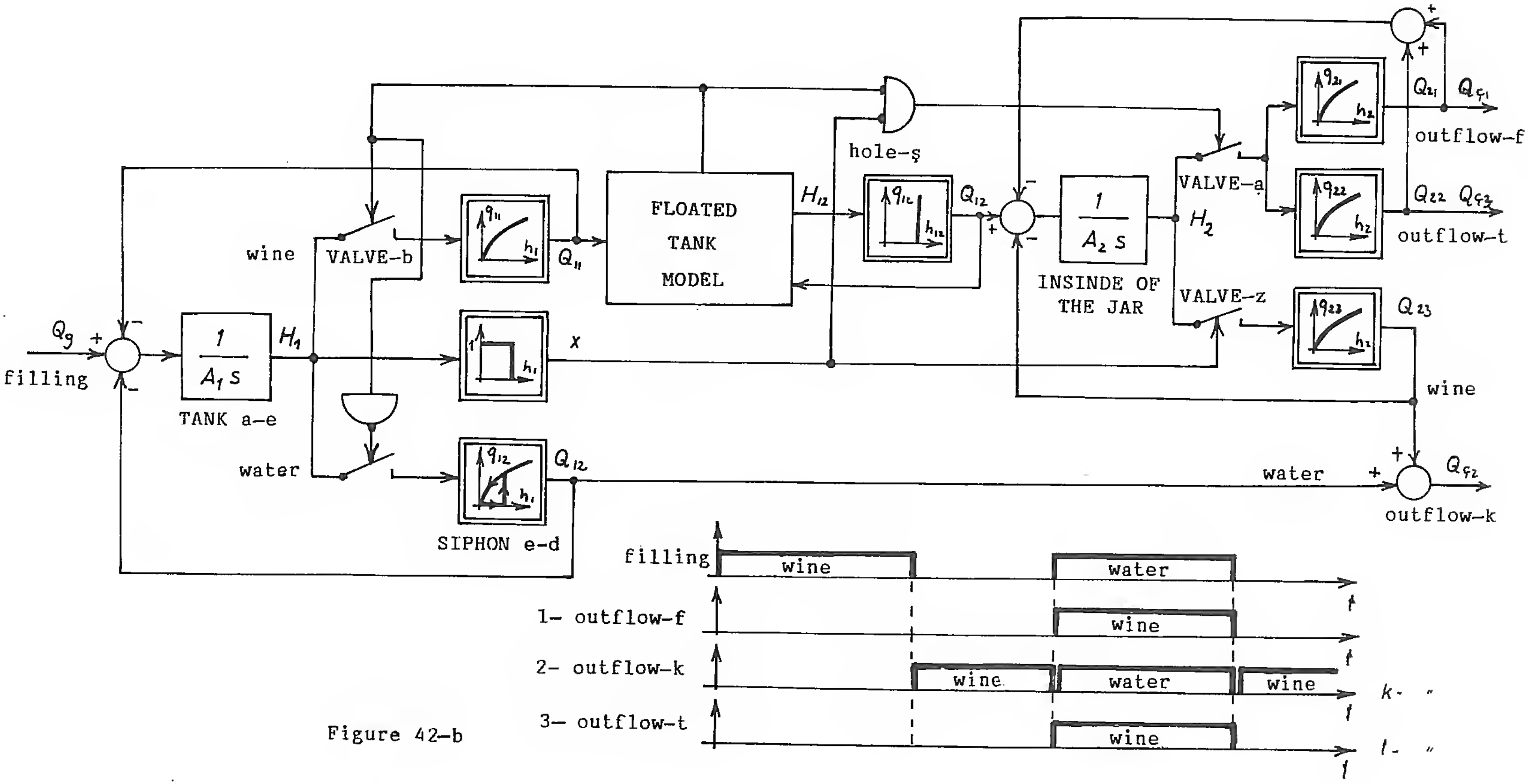
Figure 41–b

Model 42-A Jar With a Triple Free-Flow Outlet That Does Pour Out the Wine From the Middle Outlet As Soon As the Filling of the Wine in the Jar is Stopped; When Water is Poured As Second into the Jar, Then the Wine Stops Discharging From the Middle Outlet and Water Discharges From It, the Wine Begins to Discharge From the Other Two Outlets; If the Inpouring of the Water is Stopped the Wine Again Comes Out From the Middle Outlet and So On (Figure 42-a)

The wine which is poured first into the jar flows into the tank **a-e**. The float **ţ** in this tank rises and the valve **z** connected to it closes. The wine flows from the tank **a-e** through the pipes **a-h** and **c-h** (the level **d** of the siphon **e-d** is higher than the level **c**), and the valve **b** in the floated tank **b-m** found in tank **ķ** (see Motif 5). Through the hole **m** or over the edges of the floated tank **b-m**, the wine flows first into the tank **ķ**, then into the tank **s̄-ş** and at last through the hole **ş** on **s̄-ş** into the jar. The valve **a** connected to the floated tank is closed all the while the filling continues or the tank **b-m** is full. At the end of the uninterrupted filling the wine in the tank **a-e** flows into the tank **b-m**, the float **ţ** sinks and the valve **z** opens. Thus, the wine in the tank **s̄-ş** starts to flow out through the valve **z** and the pipe **k**. The outflowing wine from the tank **s̄-ş** is supplied by the jar which is connected through the hole **ş**. But, as the flowrate of the valve **z** is more than the flowrate of the hole **ş** the level of the wine in the tank **s̄-ş** can never reache the level of the valve **ạ**. For this reason, after the wine flows out from the tank **b-m** through the hole **m**, and the float **l** rises closing the valve **b** and opening the valve **ạ**, no wine flows out from the pipes **f** and **t**.

If water is started to be filled, the float **ţ** in the tank **a-e** rises again and the valve **z** connected to this float closes. Now, since the valve **b** is closed, the water in the tank **a-e** starts to flow out from the siphon **e-d-v** and the pipe **k**. As the valve **z** is closed the level of the wine in the tank **s̄-ş** rises, the wine passes through the open valve **ạ** and flows out from the pipes **f** and **t**.

If the filling action of the water is interrupted the siphon **e-d** empties the water in the tank **a-e**, the float **ţ** sinks and the valve **z** reopens. In this position the wine, supplied from the hole **ş**, flows through the valve



filling
wine
water
TANK a-e
VALVE-b
SIPHON e-d
FLOATED TANK MODEL
hole-ş
INSINDE OF THE JAR
VALVE-a
VALVE-z
outflow-f
outflow-t
outflow-k
1- outflow-f
2- outflow-k
3- outflow-t

Figure 42-b

z and pours out from the pipe **k**. This procedure can be reproduced as long as the wine is unconsumed and the water is poured into the jar.

The block diagram of the system, and a diagram showing the flow places and orders of the liquids are given in Figure 42-b. As seen in the block diagram the valves **b** and **ạ** are controlled by a floated tank (see Motif 5). The pouring out of the wine from the pipes **f** and **t** depends also on the existence of the water in the tank **a-e** (**x**=**0**). Thus, in the block diagram the hole **ş** is characterised by the logic element "and".

Model 43-A Jar That Pours Out From Its Turned-on Tap Three Different Kinds of Liquids in the Same Order That They Are Poured In (Figure 43-a)

The first liquid that is poured into the jar through the hole **t** runs into the upper tank which contains two double siphons and an overflow pipe (see Motif 2). The double siphon **a-d-ḫ** whose upper level is lower than the other, passes the first liquid, which is poured continuously into the jar, to the tank **k**. The float **l** inside this tank raises and closes the valve s. The second liquid, that is poured after a short while of interruption through the hole **t** into the jar, is transmitted into the tank **ş** through the siphon **b-e-ţ** which has a higher level, since the double siphon **a-d-ḫ** is plugged. The float in the tank **ş** also raises and closes the valve **ạ**. The third liquid that is poured into the jar flows over the overflow pipe **c** into the tank **z** since the double siphons **a** and **b** are plugged.

When at the end of the filling the tap **k̇** is turned on, the first liquid in the tank **k** pours out first. The float **l** drops along with the emptying of the tank and the valve **s** opens. The second liquid in the tank **ş** pours out following of the track **b-a-s-k̇**. The float **m** drops along with the emptying of the tank **ş** and the valve **a** also opens. At last the third liquid in the tank **z** pours out following the track **f-h-ạ-b-a-s-k̇**.

The block diagram of the system is shown in Figure 43-b. The distribution of the liquids into the tanks is realized by two double siphons plus the overflow motif (see Motif 2) and the out pouring of the liquids in the determined order is achieved by floated valves (see Motif 4). In order to reuse the system the double siphons have to be emptied or the model has to be "rewound".

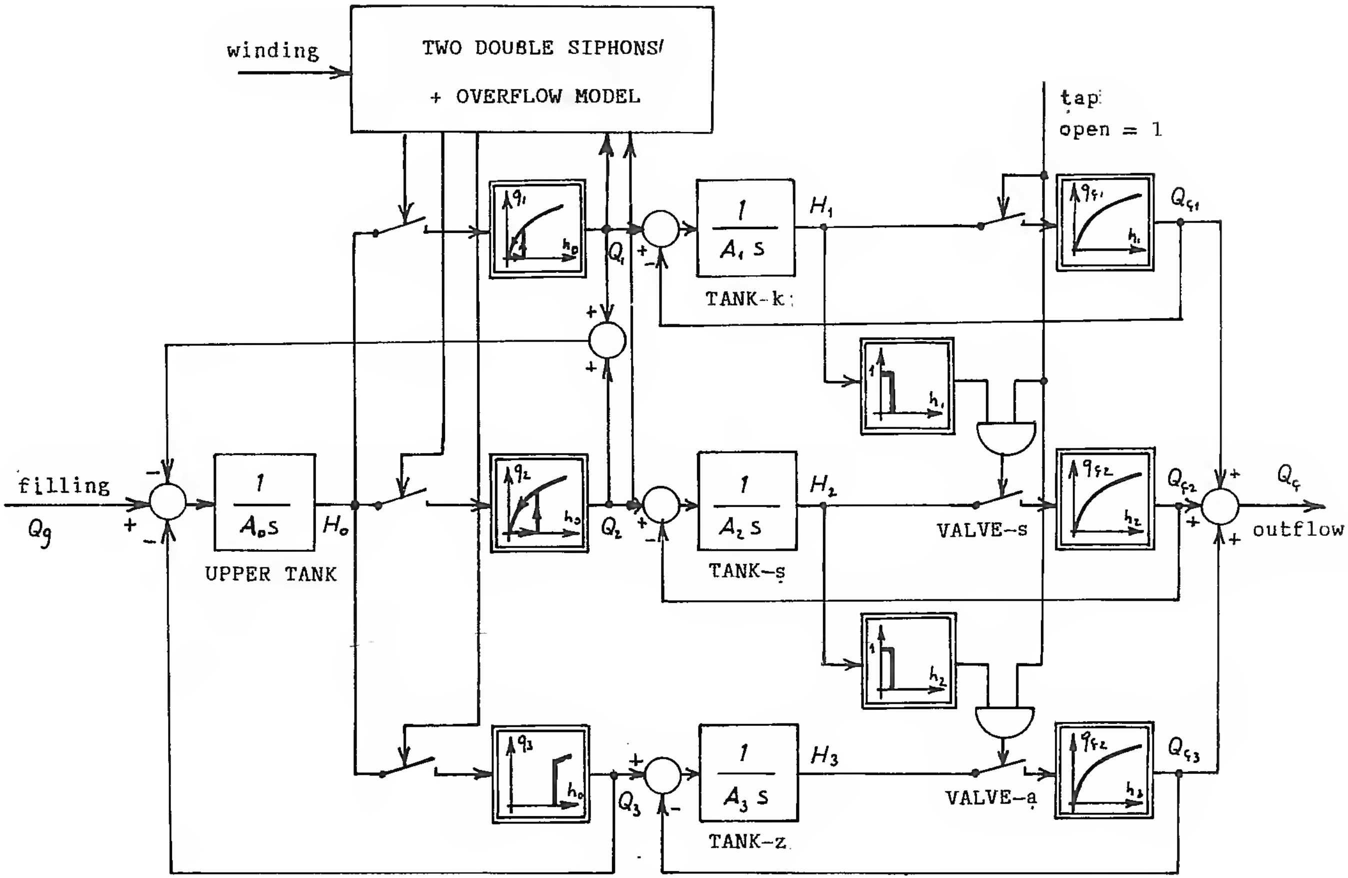

winding
TWO DOUBLE SIPHONS/
+ OVERFLOW MODEL
tap
open = 1
filling
Qg
UPPER TANK
H0
Q1
Q2
Q3
H1
H2
H3
TANK-k
TANK-s
TANK-z
VALVE-s
VALVE-a
Qf1
Qf2
Qf3
Qf
outflow

Figure 43-b

Model 44-Another Free Flow Jar (see Model 43) **That Pours out the Three Different Kinds of Liquids in the Same Order That They Are Poured into the Jar** (Figure 44-a)

The first liquid that is poured into the jar through the hole **t** flows into the upper tank which contains two double siphons and an overflow pipe (see Motif 2). The double siphon **a-d-ḥ** which has a lower upper level than the other, passes the first continuously inpoured liquid into the tank **k**. The float **l** inside this tank rises and closes the valve s since the valve ṣ at the bottom of this tank is closed at the beginning. The second liquid that is poured into the jar through the hole **t** after a short interruption flows, since the double siphon **a** is plugged, into the tank ş through the double siphon **b-e-ţ** that has a higher level. The float **e** in the tank ş also rises and closes the valve **ạ**. Since the double siphons **a** and **b** are now plugged, the last poured liquid flows through the overflow pipe **c** into the tank **z** containing a floated tank (see Motif 5). The float s does not rise as long as the third liquid is poured in the jar, or the floated tank **z-v** is full. When the filling ends, the tank **z-v** empties through the hole **v**, the float s rises and the valve ṣ connected to it opens. Along with the opening of the valve ṣ the first liquid in the tank **k** pours out following the track **ţ-ḳ**. When the tank **k** empties the float **l** sinks, the valve s opens and the second liquid inside the tank ş pours out over the track **b-a-s-t-ṣ-ţ-ḳ**. After the emptying of the tank ş, the float **e** sinks, the valve ạ opens and the third liquid inside the tank **f** pours out following the track **f-ạ-b-s-t-ṣ-ţ-ḳ**.

The block diagram of the system which is very similar to the previous one (see Model 43), is given in Figure 44-b. Only, since there is no tap in this system the outpouring is realised after the filling of the third liquid by floated tank motifs. The mutual triggering of the emptied tanks is achieved by floated valve motifs. In order to reuse the system the double siphons have to be emptied or the model has to be "rewound".

Model 45-Another Jar (see Models 43 and 44) **That Pours out Through a Tap, Different Kinds of Liquids in Brief Intervals and At the Same Order That They Are Poured Into the Jar** (Figure 45-a)

The first liquid that is poured into the jar flows into the upper tank

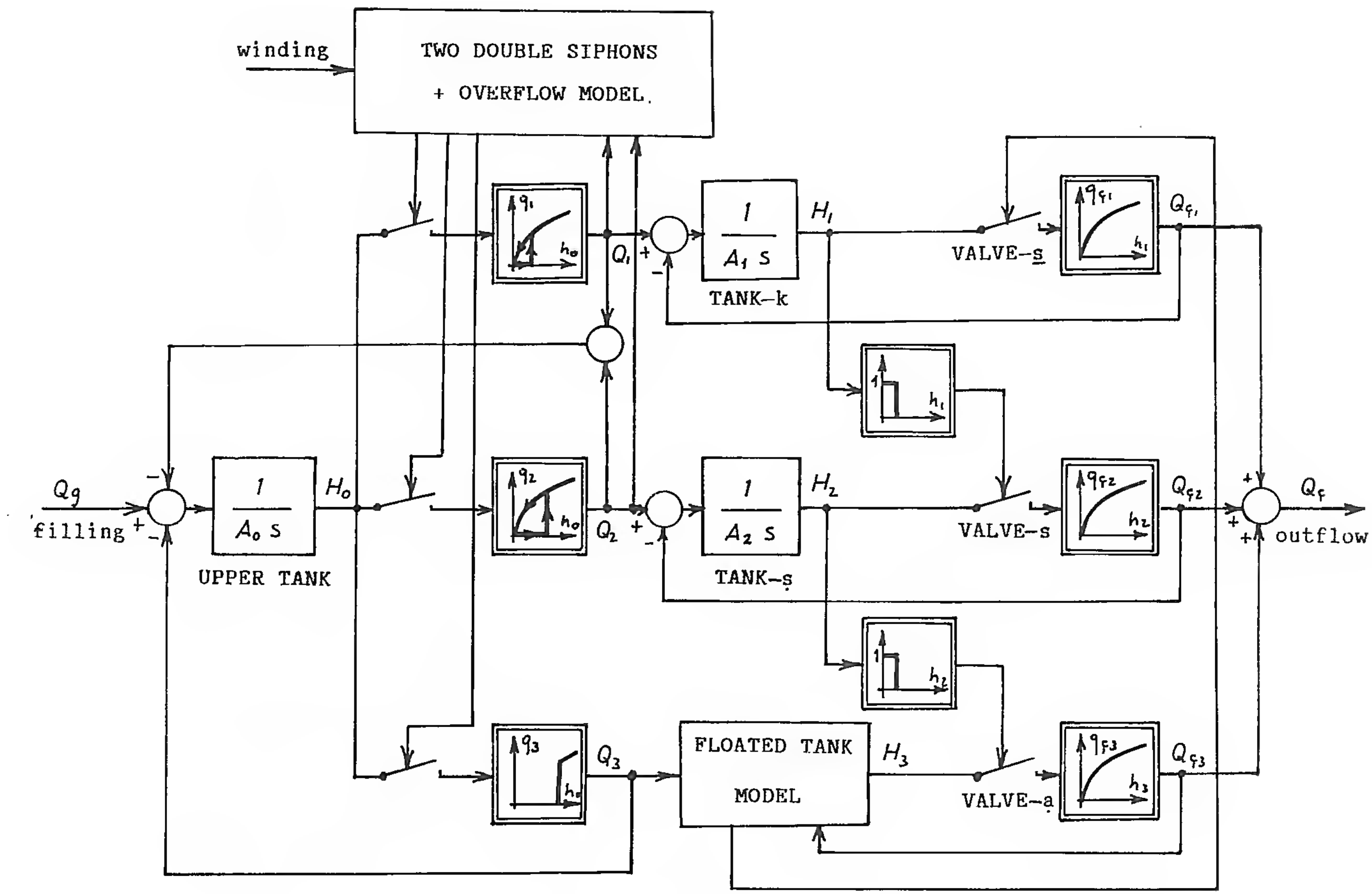

winding
TWO DOUBLE SIPHONS
+ OVERFLOW MODEL.
Qg
filling
UPPER TANK
H0
Q1
Q2
Q3
TANK-k
TANK-s
H1
H2
H3
FLOATED TANK
MODEL
VALVE-s
VALVE-s
VALVE-a
Qf1
Qf2
Qf3
Qf
outflow

Figure 44-b

b-a which contains a double siphon and an overflow pipe (see Motif 2). The double siphon with a level **a** lower than **b**, passes the first liquid, which is poured in continuously through **a-d-h** into the tank **ṭ**. While the tap **k̇** is closed the floated valve **e** which is in this tank rises and closes the valve **l**. Since the double siphon **a** is plugged, the second liquid that is poured into the jar after a short interruption flows over the overflow pipe **b** into the tank **c**. After the filling, if the tap **k̇** is opened the first liquid which is in tank **ṭ** pours out. When the tank **ṭ** empties the float **e** sinks and the valve **s** opens. The second liquid in tank **c** flows over the pipe **y-l** in a B-type floated tank (see Motif 5). In the B-type floated tank **z-v** exists siphon **m**. The aim of this siphon is to form a brief interval between the outpouring of the first and second liquids. The second liquid flowing through the siphon goes out from the tap **ḳ**. If desired, as in Model 43, by increasing the number of the tank **ṭ**, more than two kinds of liquids can be outpoured in brief intervals.

As seen in Figure 45-b the block diagram of the system is identical to the block diagram of the Model 44. The liquids are prevented from getting mixed by the brief intervals between the outflow of the liquids, which is achieved by a B-type floated tank.

Model 46-A Jar That Pours Out From its Tap the Different Kinds of Liquids in the Reverse Order That They Are Poured In (Figure 46-a)

The first liquid that is poured into the jar through the hole **f** runs into the upper tank **b-a** which contains a double siphon and an overflow pipe (see Motif 2). The double siphon with level **b** lower than **a**, passes the continuously inpoured liquid over **b-ş-d-e-h** into the tank **h-ạ**. The air in this tank goes out following the way **y-v-c-a**. The second liquid that is poured through the hole **f** after a short interruption flows through the overflow pipe **a** into the tank **c-v**, since the double siphon **b** is plugged. The air of this tank goes out through the pipe **ṭ**.

After the end of the filling, when the tap **k̇** is turned on, since the air entrance to the tank **h-ạ** is prevented, first the second liquid befinding in tank **c-v** flows out following the way s-**m**-**k̇**. After the tank **c-v** got emptied, the air enters into the tank **h-ạ** over the pipe **v-y** and the first

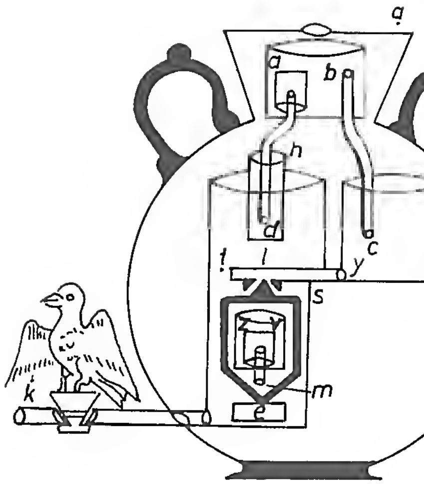


Figure 45—a (T)

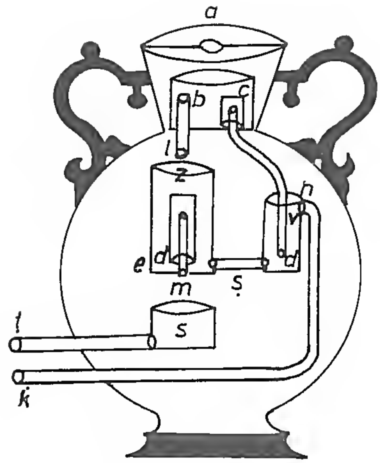


Figure 48-a (T)

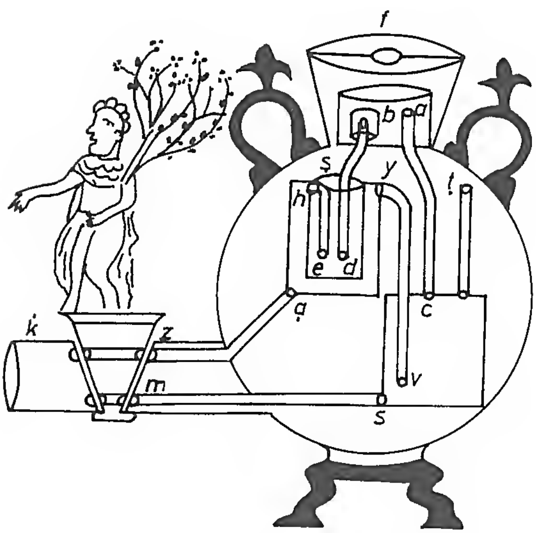


Figure 46-a (T)

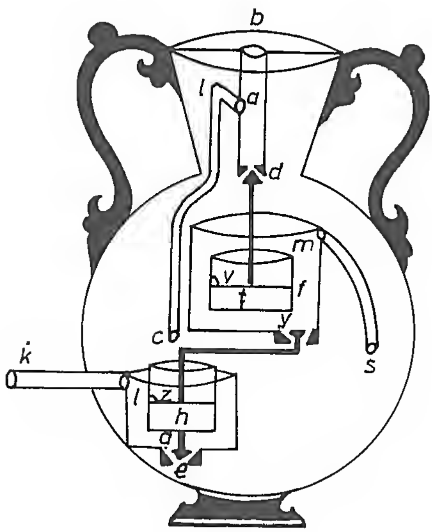


Figure 47-a (T)

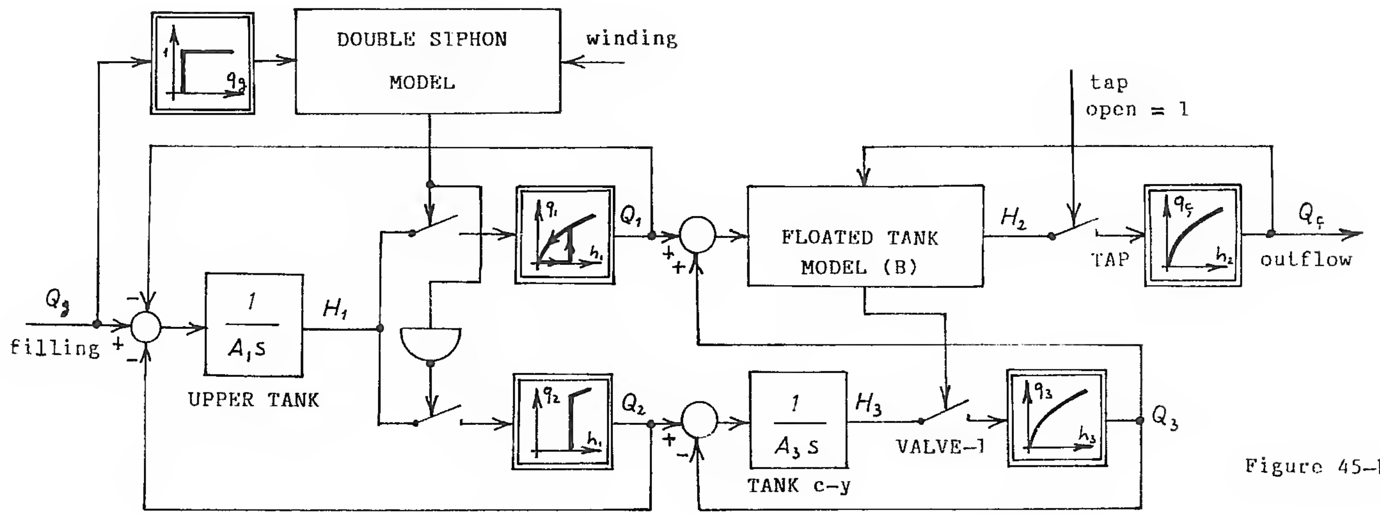


Figure 45-b

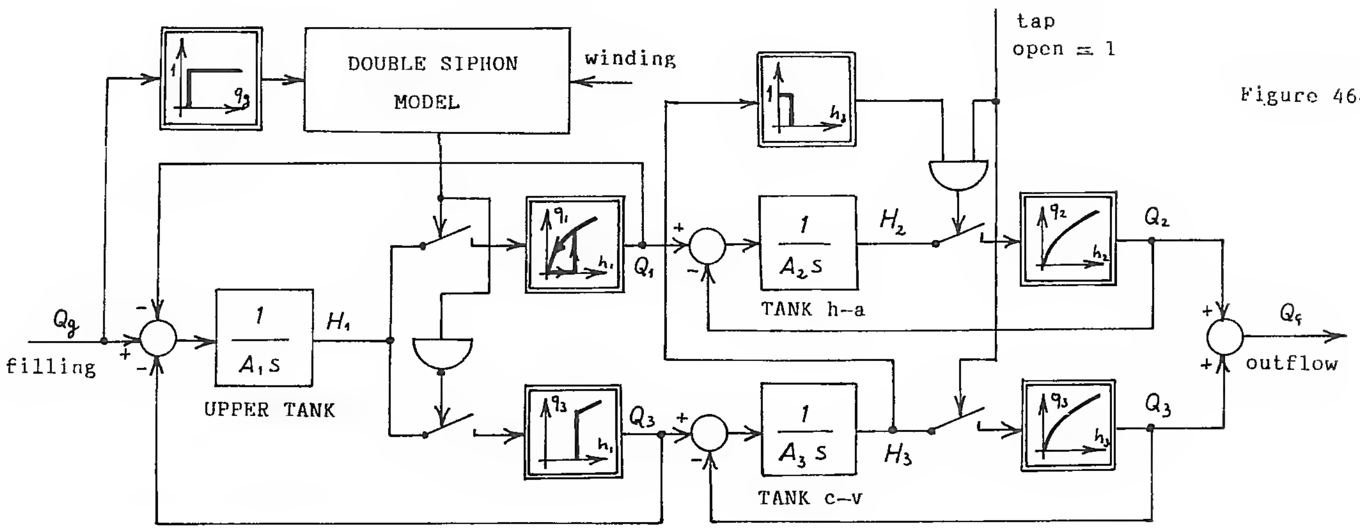


Figure 46-b

liquid also flows out following the way **ạ-z-k̇**. If desired by increasing the number of the tanks **h-ạ**, many kinds of liquids can be outpoured in reverse order to that by which they are inpoured.

As seen in the block diagram given in Figure 46-b, double siphon motif is used to collect the liquids in different tanks (see Motif 2), and the outpouring sequence is achieved by air control motif (see Motif 7). For the outpouring of the first liquid the tank **c-v** has to be emptied and the tap **k̇** should be turned on.

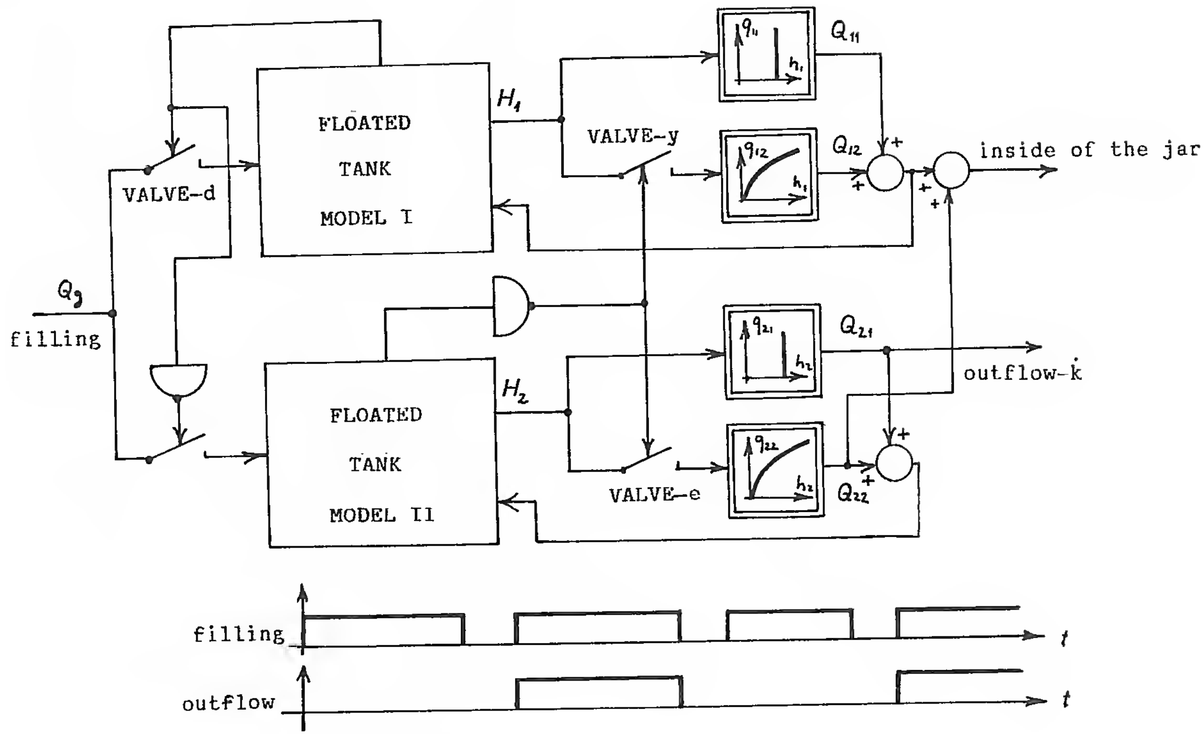
Model 47-A Jar in Which the Pouring out or Not of the Filled Liquid Can be Regulated by the Filling Interruptions (Figure 47-a)

The liquid which is poured into the jar through the hole **b** passes the open valve **d** and flows into the tank **f** that contains a floated tank (see Motif 5 - at the beginning the valve **y** is closed). As long as the filling continues and the floated tank **v** is full, the float **ţ** cannot raise and the valve **d** does not close. When the liquid reaches the level **m** in the tank **f**, it runs over the pipe **m-s** into the jar.

If pouring into the jar is interrupted for a short while, the tank **v** empties through the hole **v** during this interruption and the valve **d** closes along with the rising of the float **ţ**. The poured liquid now follows the track **a-l-c** and flows into the tank **l** that contains another floated tank. The liquid overflowing the floated tank **z** runs out over the pipe **l-k̇**. As long as the tank **z** is full or the filling continues uninterrupted the liquid flows out from the jar.

If pouring into the jar is interrupted for the second time, the tank **z** empties, the float **h** rises and the valves **y** and **e** connected to it open. As, by the open valve **y** the tank **f** and by the valve **e** the tank **l** empties, the system returns to it's original state. By repeating these procedures in desired frequencies and intervals the pouring out or not of the liquid can be regulated.

The block diagram of the system as seen in Figure 47-b is formed by the model of two floated tanks (see Motif 5). The first floated tank controls the filling by the valve **d**. The second floated tank controls the valves **y** and **e** and brings the system back to its original state. This



FLOATED
TANK
MODEL I
FLOATED
TANK
MODEL II
VALVE-d
VALVE-y
VALVE-e
H_1
H_2
Q_g
filling
Q_{11}
Q_{12}
Q_{21}
Q_{22}
inside of the jar
outflow-k
filling
outflow
t
t

Figure 47-b

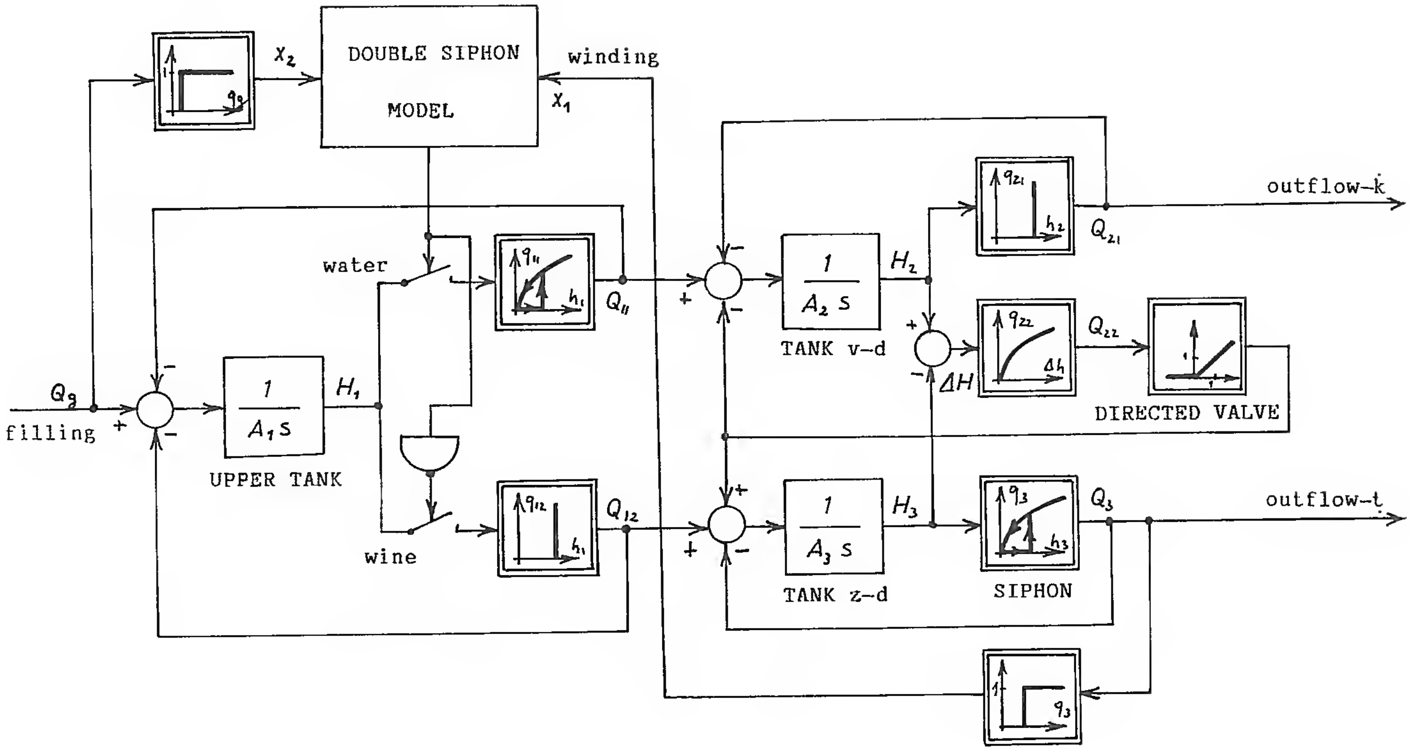
system reminds the frequency division circuits used in modern electronic circuits. If the in-pouring procedure is interrupted in determined intervals, the frequency of the out-poured liquid becomes half of the frequencies of the filling interruptions.

Model 48-Another Jar (see Model 47) **in Which the Outflow Place of the Filled Liquid Can Be Regulated by the Filling Interruptions** (Figure 48-a)

The first liquid (in the model, water) which is poured into the jar through the hole **a** flows into an upper tank containing a double siphon and an overflow pipe. The double siphon with its level **c** lower than **b**, passes the water out of the jar, following the way **c-d-v-h-k**. The second concentric siphon of the double siphon is connected to the tank **z-d** by the pipe **ş**. On the pipe **ş** there is a directed valve (not drawn in the figure-see Motif 14) which permits the water to flow only from the double siphon to the tank **z-d**. A part of the inpoured water flows over the pipe **ş** to the tank **z-d**, but as the level of the siphon in this tank is higher than the level **v**, the outflow cannot be achieved through this tank.

When, after a short interruption, one begins to pour wine into the jar, the wine which is poured into the upper tank flows over the overflow pipe **b-l** into the tank **z-d**, since the double siphon is now plugged. When in the tank **z-d** the wine mixed with water reaches the upper level **d** of the siphon, the outflow begins to follow the way **d-s-ţ**. If the inpouring of wine is ended then all the liquids in the **z-d** tank, and in the upper tank and the double siphon are outpoured over **c-d-ş** by the siphon **d**. So when the pouring of the water recommences the system returns itself to its original state.

The block diagram of the system is seen in Figure 48-b. The interesting point in this model is that the double siphon which regulates the outflow way of the filled liquid (see Motif 2) is automatically rewound. In the preceding models the double siphons had to be emptied or "rewound" by hand after complicated manipulations. Here, this operation is realised automatically by a directed valve and a siphon.



DOUBLE SIPHON MODEL
winding
filling
water
wine
UPPER TANK
TANK v-d
TANK z-d
DIRECTED VALVE
SIPHON
outflow-k
outflow-t

Figure 48-b

As in Model 47 this system works as a frequency division circuit. If, as stated here, two different liquids are being used, because of the passage from the tank **v-d** to the tank **z-d**, the liquid which is not affected from the mixing must flow into the tank **z-d**. A small quantity of water mixed in wine cannot be determined, but contrary, a little wine mixed in water is immediately noticed.

Model 49-A Jar Filled by Water and Wine, Which Pours Them in Succession and in Predetermined Quantities When its Tap is Turned On, and Repeats This Action Once More (Figure 49-a)

Water which is first poured into the jar through the hole **ṭ** flows into an upper tank containing a double siphon and an overflow pipe. Since the level **b** of the double siphon is lower than **a**, the water flows into the tank **v**, following the way **b-ḥ-l**. As the tap is turned off, with the rising of the float **e**, the valve **e** closes. When the water in this tank reaches the level **t** it passes into the tank **m** through the pipe **t-ş**. The float **d** also befinding in this tank rises and the valve **d** closes. Some quantity of water goes into the tank **h** through the pipe **f-h** and the valve **c**, but with the rising of the float **c** the valve **c** also closes. Now the tanks **v** and **m** are filled with water to the level **t-ş**. The wine which is poured into the jar through the hole **ṭ**, flows from the overflow pipe **a-m** into the tank **h** since the double siphon is plugged. When the level of the wine which is mixed with water found on the bottom of the tank reaches **n**, it flows into the tank **ş** through the pipe **n-k**, so that at the end the tanks **h** and **ş** are now filled with wine to the level **n-k**.

When the tap **k̇** is turned on, first the water, which is in the tank **v**, flows out. When the tank **v** empties the valve **e** opens and the wine in the tank **h** flows out following the way **z-v-s-k̇**. When the tank **h** empties the valve **c** opens and the water in the tank **m** flows out following the way **f-h-z-v-s-k̇**. At last when the tank **m** empties the valve **d** opens and the water in the tank **ş** flows out following the way **ş-m-f-h-z-v-s-k̇**. These successive events can be stopped temporarily by closing the tap **k̇**.

The block diagram of this system is given in Figure 49-b. Different versions of this system realised by floated valves (see Motif 4) can be

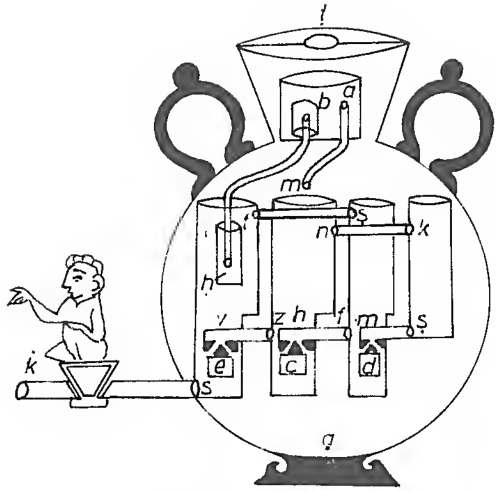


Figure 49-a (T)

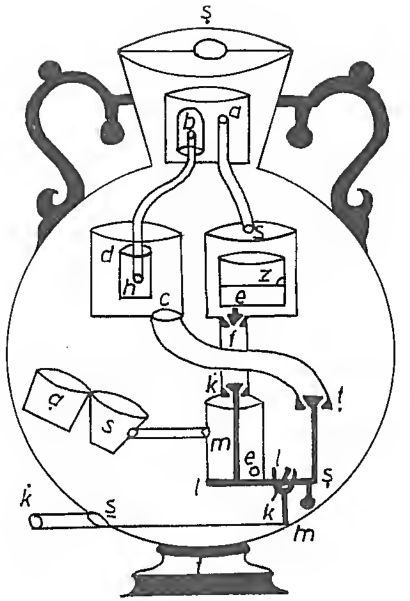


Figure 50-a (T)

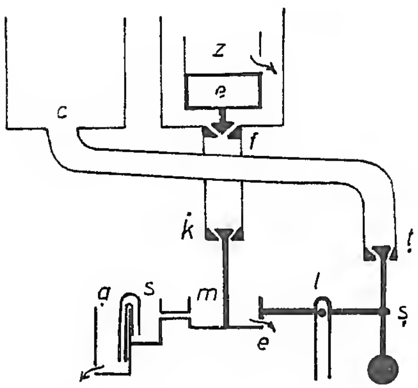


Figure 50-b

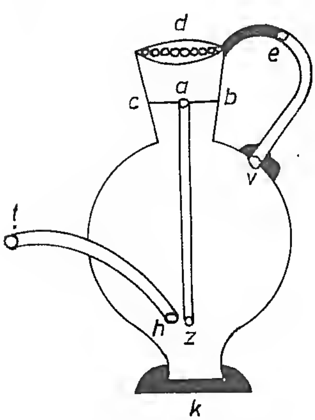


Figure 51-a (T)

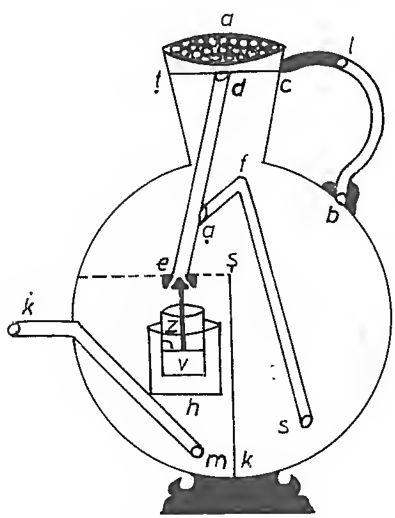
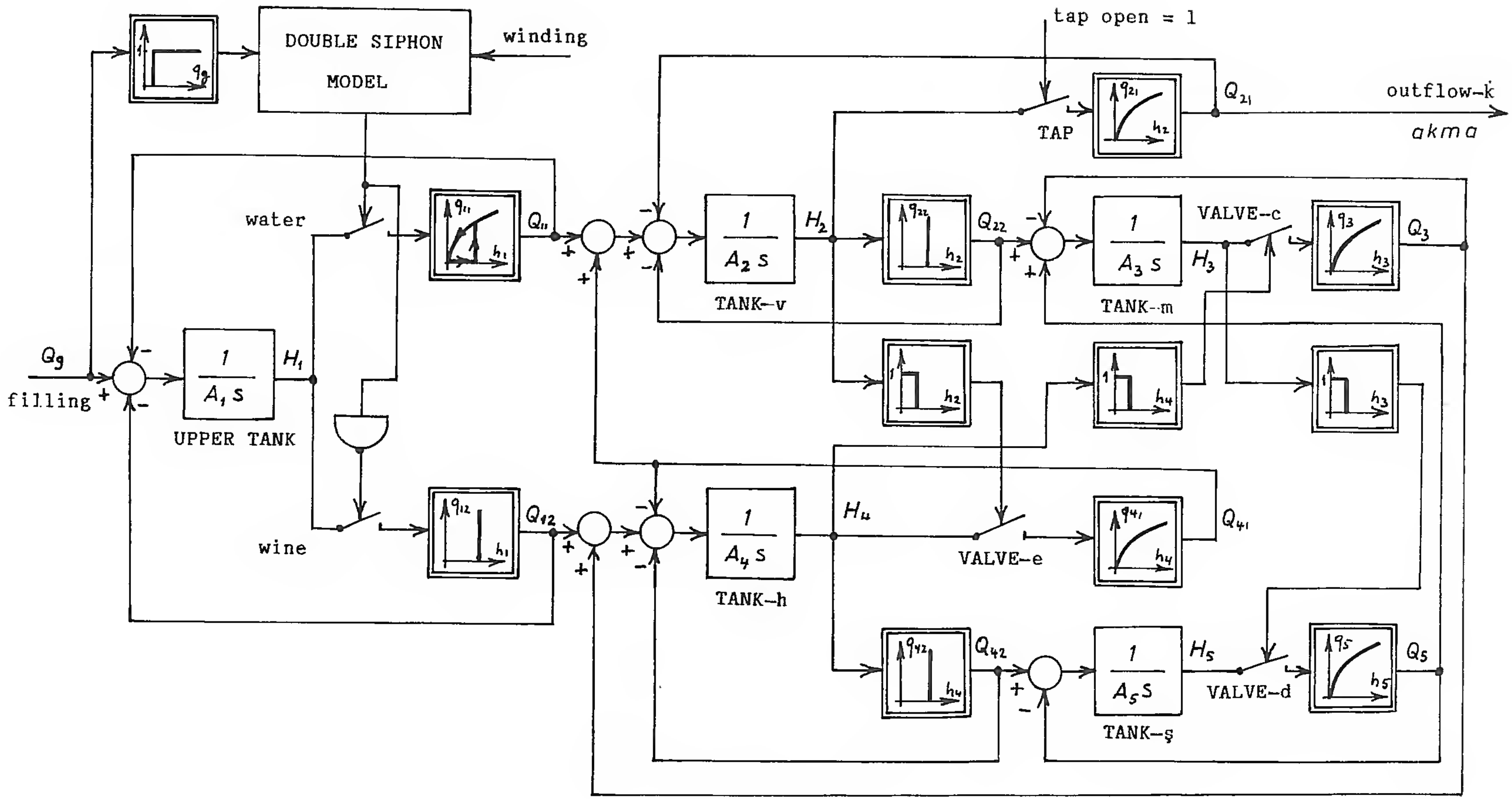


Figure 52-a (T)



DOUBLE SIPHON MODEL
winding
tap open = 1
TAP
outflow-k
akma
water
wine
UPPER TANK
TANK-v
TANK-m
TANK-h
TANK-ş
VALVE-c
VALVE-e
VALVE-d
filling

Figure 49-b

derived. This model works like successively connected electronic circuits which trigger each other mutually.

Model 50-A Jar Which After Being Filled by Wine and Water, Pours Out a Determined Quantity of Water and Wine Alternately in Succession Till it Empties (Figure 50-a)

The wine which is first poured into the jar through the hole ş flows into the upper tank containing a double siphon and an overflow pipe. As the level **b** of the double siphon is lower than **a**, the wine flows into the tank **d**, following the way **b-h-d.** The valve ţ which is beneath the tank **d** is tied to a balance (see Motif 6-balanced valve). When the balance tanks are empty, the weight ş inclines the balance to the right and the balance rod **l-ş** closes the valve ţ (in Figure 50-b a reconstruction of the balanced valve and its tanks is given). The water which is poured next into the jar through the hole ş flows from the overflow pipe **a-s** into the tank **s** which contains a floated tank (see Motif 5), since the double siphon is plugged. As long as the tank **z** on the float is full, or the filling continues, the valve **f** which is tied to the float remains closed.

When the uninterrupted filling finishes, the tank over the float empties through the hole **z** and with the rising of the float the valve **f** opens. Since the valve ķ is also open, the water on the tank s pours into the tank **m** which is on the left arm of the balance **l-ş** and overflowing from this tank pours out through the pipe **ṣ-k̇**. A little of the water poured into the tank **m** flows through the pipe **m-s** into the tank s which is on the same arm of the balance. When the tank s is full the water flows suddenly through a siphon into the tank ạ adjacent to it (see Figure 50-b). This sudden transfer disturbs the equilibrium of the balance **l-ş**. Thus, the balance inclining to the left closes the valve **k̇** on the left arm and opens the valve ţ on the right arm. At this position the wine flows out through the pipe **ṣ-k̇**. The water in the tank **m** which is in the left arm of the balance empties through the hole **e**, and the water in the tank ạ empties through a hole at the bottom of the tank. The water in these tanks flows out mixed with the outpouring wine (in the original figure the siphon and the hole are not shown). After the emptying of the tank ạ the equilibrium of the balance changes again and the balance

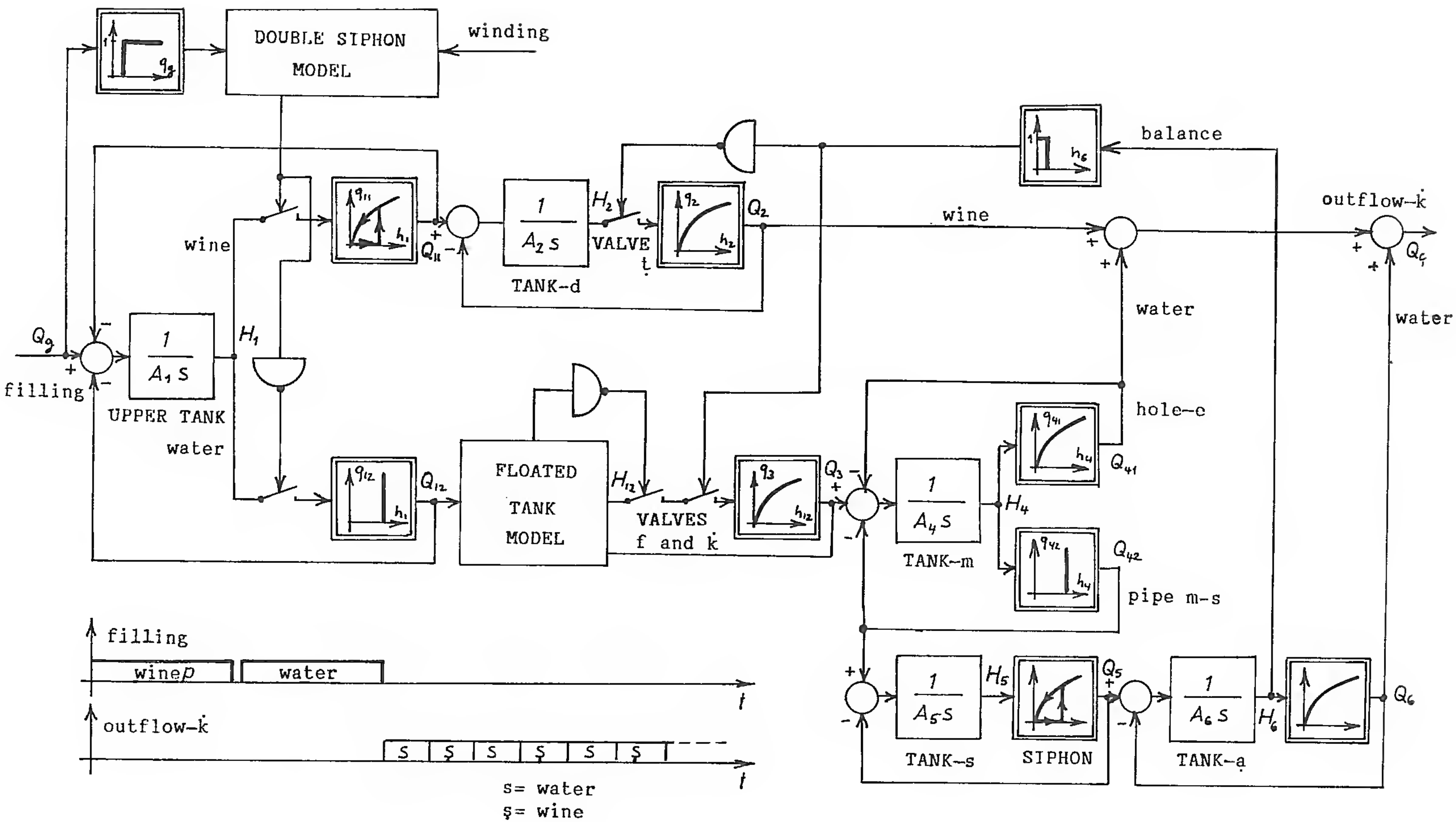

DOUBLE SIPHON MODEL
winding
balance
outflow-k̇
wine
water
filling
UPPER TANK
TANK-d
VALVE ṫ
FLOATED TANK MODEL
VALVES f and k̇
hole-c
TANK-m
pipe m-s
TANK-s
SIPHON
TANK-a
filling
wine
water
outflow-k̇
s= water
ş= wine

Figure 50-c

inclines to the right. Then the valve **ţ** closes, the valve **k̇** opens and water begins to flow out from the pipe **ṣ-k̇.**

The block diagram of this oscillator-like system is seen in Figure 50-c. The mixing of some quantity of water into the wine is a fact which is appraised as an unimportant detail in the text and can easily be prevented. The difficulty in realising this system lies in achieving the sensitive equilibrium of the balance mechanism.

Model 51-A Jar With a Free Outlet in Which One Can Arrange the inpoured Liquid at the Same Time to Flow out or Not (Figure 51-a)

The liquid poured into the jar through a sieve like plate **d** flows first into a tank on the neck of the jar which is formed by the partition **c-b.** As long as the hole **e** on the handle is kept open the liquid flows through the pipe **a-z** and collects at the bottom of the jar (see Motif 7). If the user of the jar closes the hole **e** with his hand, from which the air goes out, the liquid begins to flow out following the way **a-z-h-ţ** because of the level difference **a-ţ** between the upper tank and the outlet pipe. This operation continues till the level of the liquid in the jar reaches **ţ**. From this level on, all of the liquid poured into the jar flows directly out. To bring the system to its original state the jar must be emptied by lying it on it's side.

The block diagram of the system is seen in Figure 51-b. In the diagram the free flow curve of the tank block slides to the left in proportion with the level difference **a** to **ţ**. It is stated in the work that this jar is used in drinking parties to spare certain persons from their drinks.

Model 52-A Jar With a Free Outlet, Which Pours out or Not the Prefilled Wine, When Water is Poured in (Figure 52-a)

First, wine is poured into the jar through the sieve-like lid **a.** The wine that passes from the upper tank on the neck of the jar through the pipe **d-e** runs into the tank **h** that contains a floated tank, which is placed under the valve **e.** The wine overflowing from the tank **h** runs into the left partition in the body of the jar. The air is forced to go out through

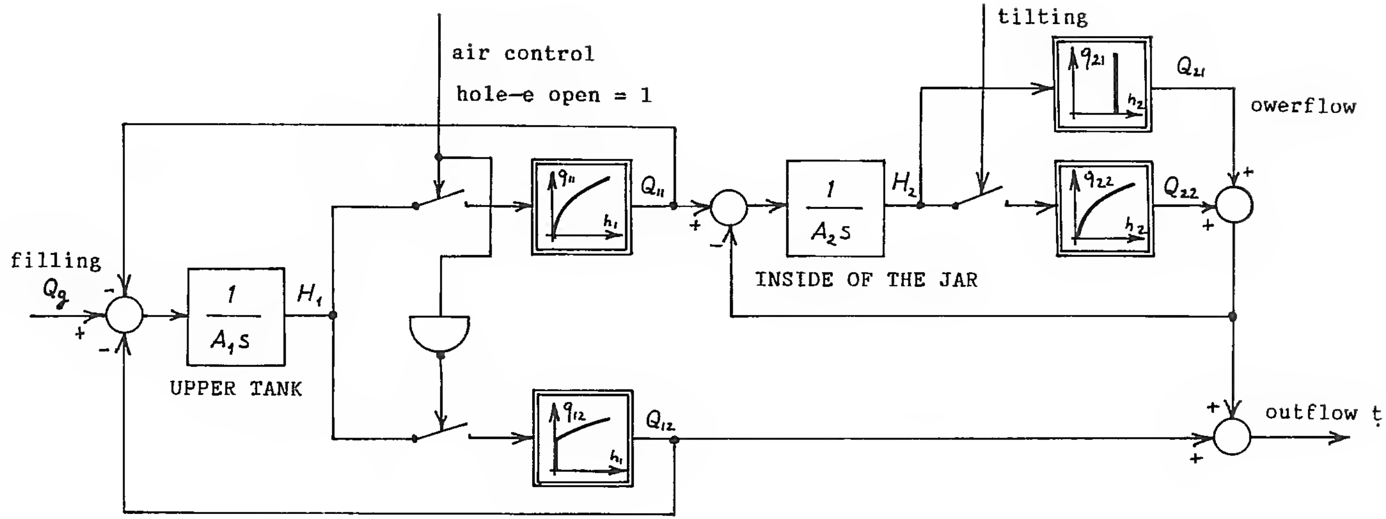

air control
hole-e open = 1
tilting
filling
Q_g
$\frac{1}{A_1 s}$
H_1
UPPER TANK
q_{11}
h_1
Q_{11}
q_{12}
h_1
Q_{12}
$\frac{1}{A_2 s}$
H_2
INSIDE OF THE JAR
q_{21}
h_2
Q_{21}
q_{22}
h_2
Q_{22}
owerflow
outflow t

Figure 51-b

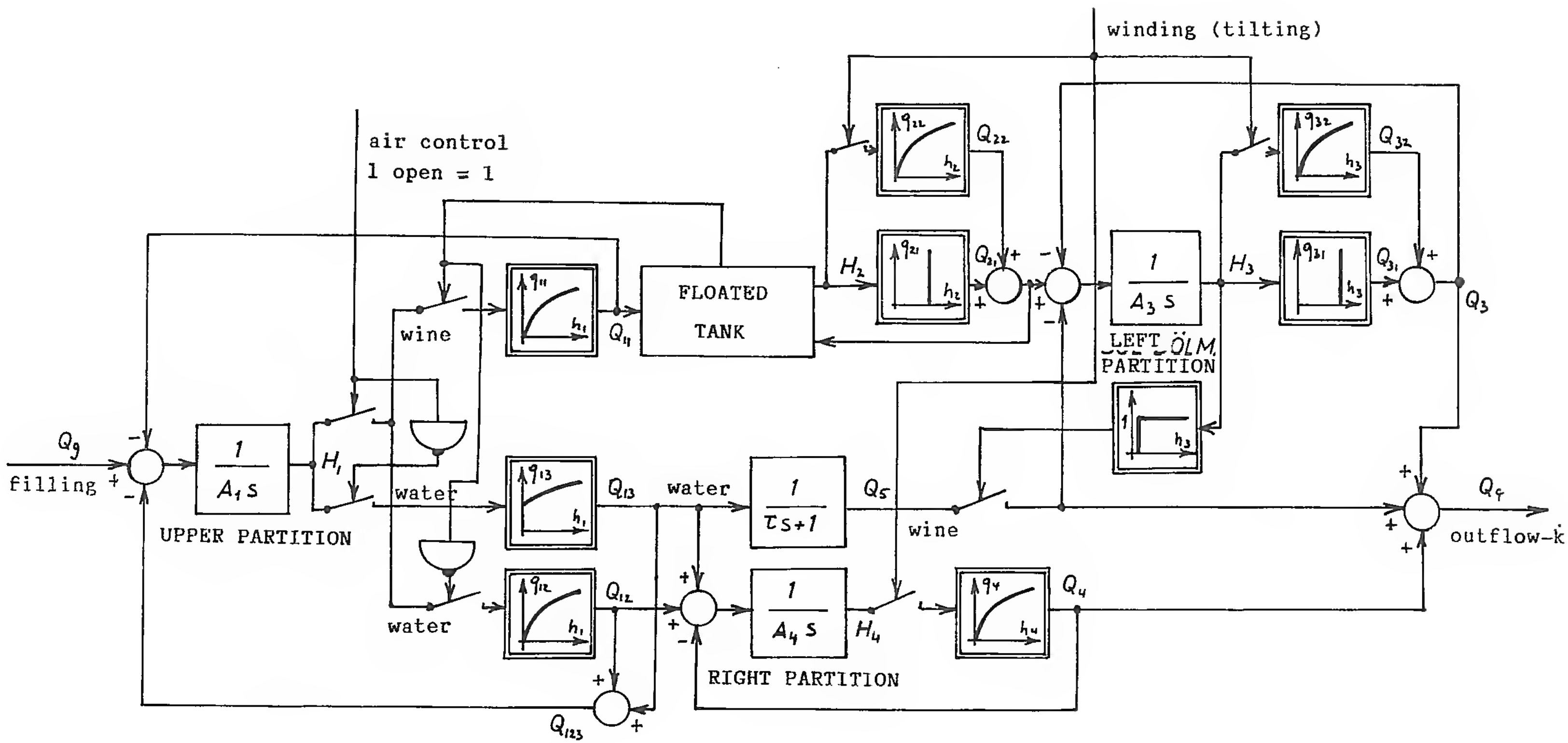

winding (tilting)
air control
1 open = 1
FLOATED
TANK
UPPER PARTITION
LEFT ÖLM. PARTITION
RIGHT PARTITION
filling
outflow-k
wine
water
wine
water
water
wine
Q9
H1
H2
H3
H4
Q11
Q12
Q13
Q123
Q21
Q22
Q31
Q32
Q3
Q4
Q5
Q7

Figure 52-b

the hole l following the pipe **b-l** camouflaged on the handle. When the uninterrupted filling ends, the floated tank empties through the hole **z**, the float **v** rises and the valve **e** closes. Now, if water is poured into the lid **a**, since the valve **c** is closed, the water runs into the right partition following the way **d-a-f-s**, while the air goes out through the pipe **b-l**. If the hole **l** is closed by the hand of the user, the pressure formed inside the jar by the inpoured water causes the outpouring of the prefilled wine in the left partition of the jar through the pipe **m-k**. Thus, the pouring out or not of the wine is controlled by opening or closing the hole **l** on the handle (see Motif 8 - pressure equilibrium).

The block diagram of the system is seen in Figure 52-b. The hole **l** being open (state 1) the inpoured wine collects in the left partition, after the interruption, when the valve **c** is closed, the inpoured water gathers in the right partition. When the hole **l** is closed (state 0), the pressure formed by the water which flows in at a flowrate of q_{13}, causes the outpouring of the wine at a flowrate of q_5.

In the model, the relation between q_{13} and q_5 is given by a first order system, having the time constant τ. Moreover, the flow out of the wine depends on the existing of the wine in the left partition of the jar. This condition is evaluated by a switch controlled through the level h_3. To bring back to the beginning state or to rewind the system the jar has to be emptied by tilting.

Model 53-A Jar With a Free Outlet, Which Pours out or Not the Liquid in it As Desired by the User (Figure 53-a)

The liquid which is poured through a sieve-like lid **t** flows into the upper tank on the neck of the jar and from there running through the air obstacle **e-b-d** flows into the jar. The air goes out through the hole **h** following the pipe **k-h** on the handle. If the user of the jar closes the hole **h** with his hand, the level of the liquid on the upper tank rises since the air exit from the interior of the jar is blocked. When the level of the liquid in the upper tank reaches the level **c** it begins to flow out over the siphon **c-k**.

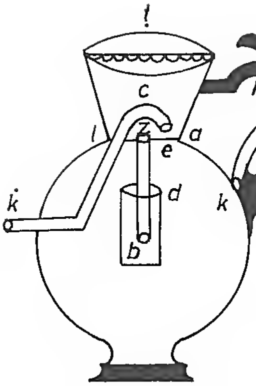


Figure 53-a (T)

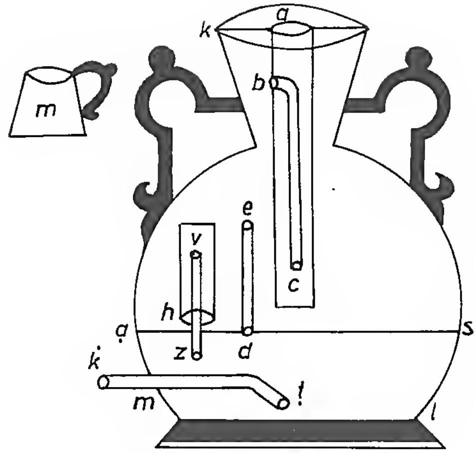


Figure 54-a (T)

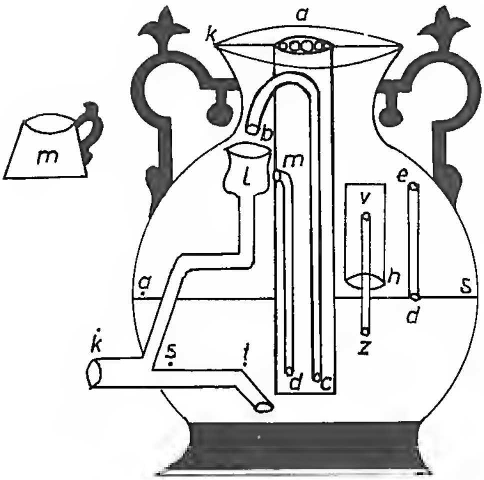


Figure 55-a (T)

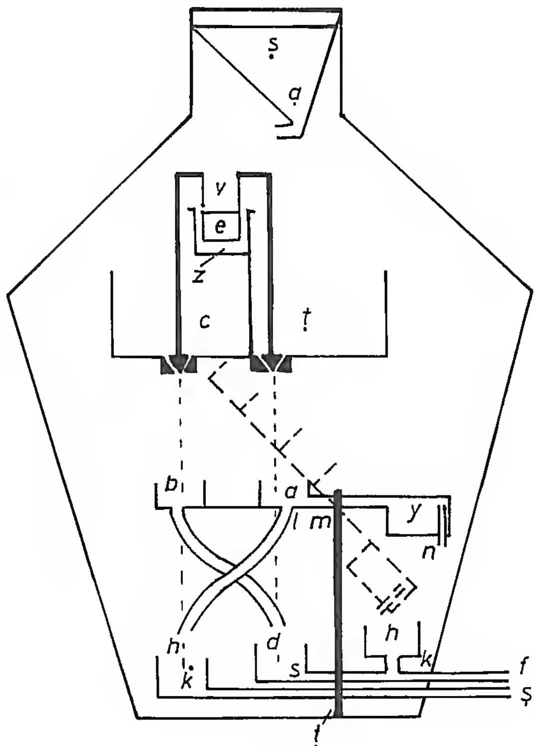


Figure 56-b

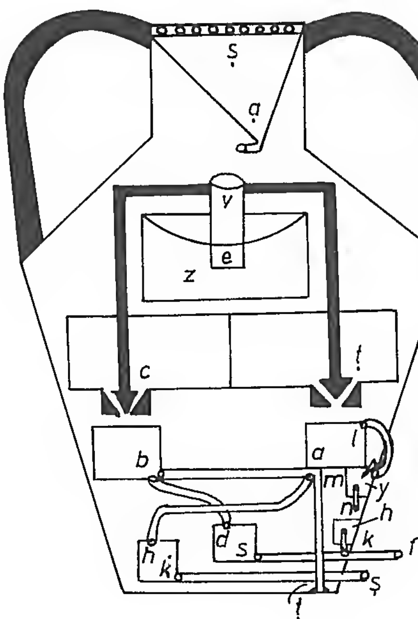


Figure 56-a (V)

The block diagram of this jar used on the drinking parties is seen in Figure 53-b. The effect is obtained by the air control motif (see Motif 7)

Model 54-A Jar Which Does Not Pour out When a Predetermined Quantity of Wine is Filled and When the Filling Finishes it Pours out the Same Quantity of Wine as Water is Poured in (Figure 54-a)

The measuring cup **m** full of wine is poured into the jar through the hole **a**. The wine passing the air obstacle **a-c-b** collects in the upper tank. The air of this tank goes out following the way **e-d-ţ-k**. The measuring cup contains sufficient wine to surpass the level **v** at the upper tank, but not enough to reach the level **m** at the lower tank. So that the wine flows over the siphon **h-v-z** into the lower tank and the air from the lower tank passes to the upper tank through the pipe **d-e**. When, after the filling ends, water is poured into the jar through the hole **a**, the air pressure formed by the water on the upper tank causes the outflow of the same quantity of wine from the lower tank (see Motif 8). This effect can be repeated till the level of the wine on the lower tank decreases to the level **ţ**.

The block diagram of the system is given in Figure 54-b. As in the model 52 the property that the same quantity of wine poures out as water is poured in is characterised by a first order block with a time constant τ. For the pouring out the wine level $\mathbf{h}_2$ in the lower tank must be sufficient. This characteristic is shown in the block diagram with a switch controlled by the level $\mathbf{h}_2$.

Model 55-Another Jar (see Model 54) **Which Does not Pour Out When a Predetermined Quantity of Wine is Filled in and After the End of The Filling, Pours out the Same Quantity of Wine or a Mixture of Wine and Water as Water is Poured In** (Figure 55-a)

As in model 54 the measuring cup **m** full of wine is poured little by

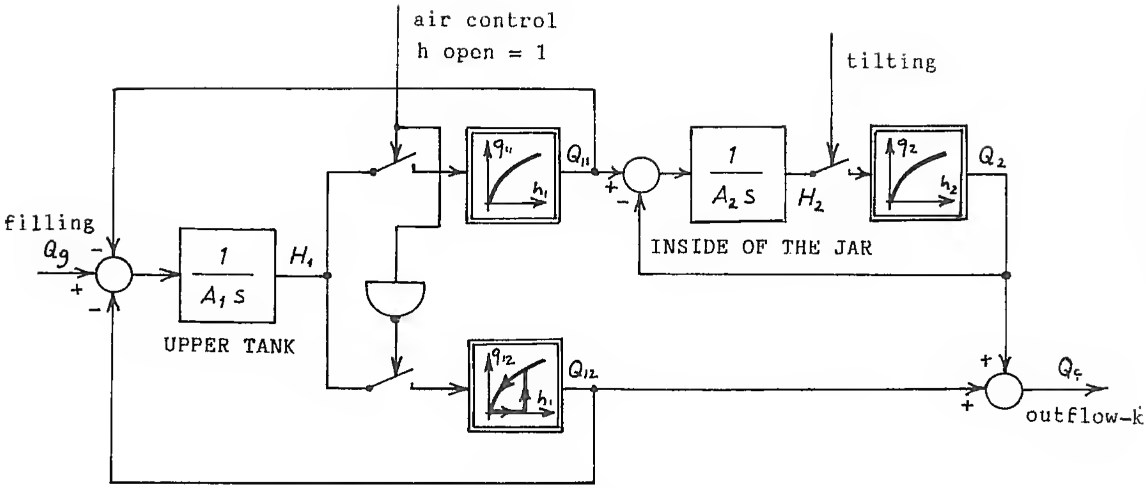


Figure 53-b

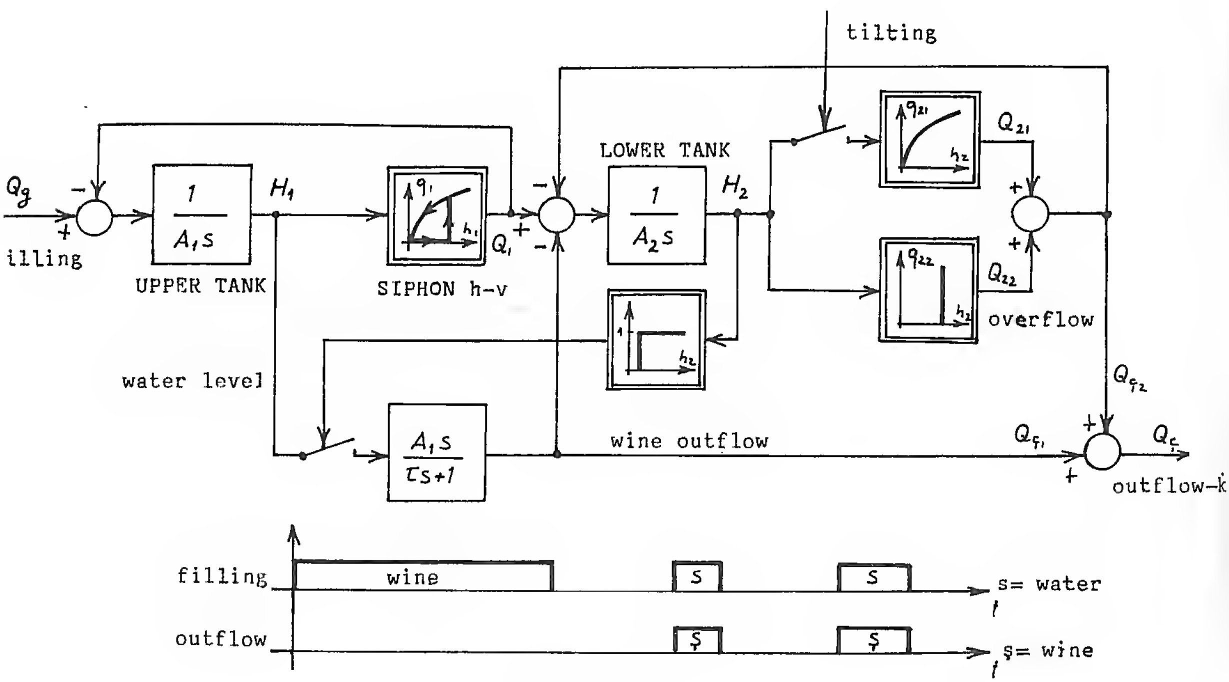


Figure 54-b

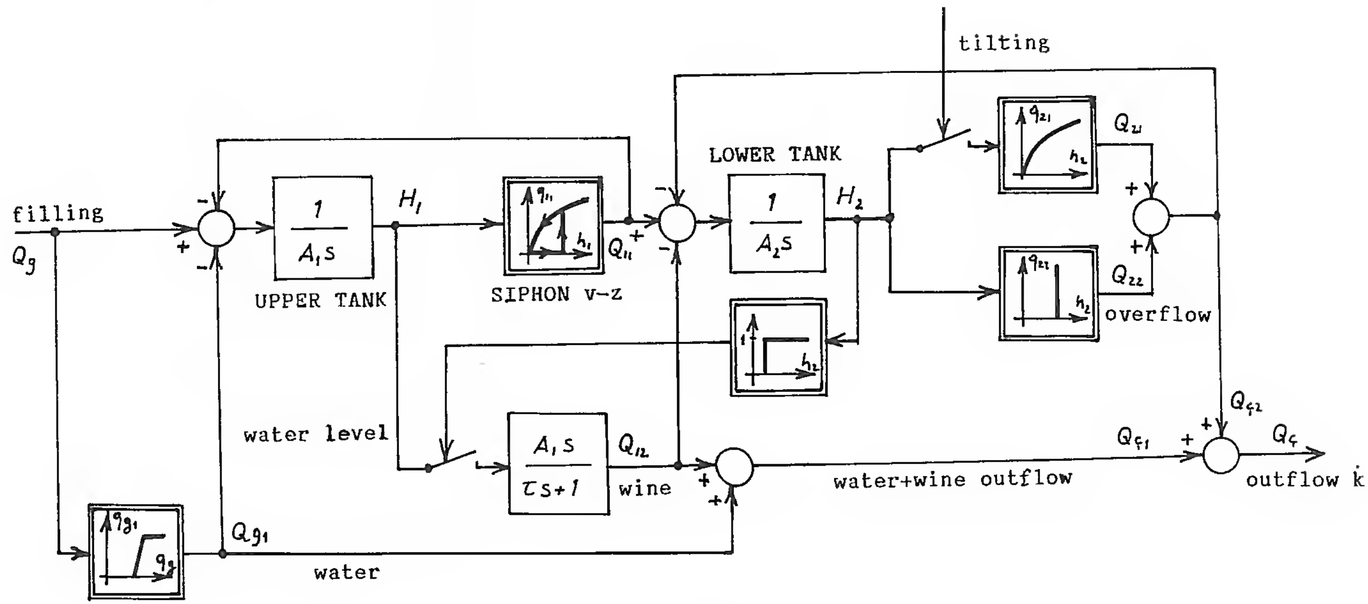
little into the jar through the hole **a**. The wine flows through the air obstacle **a-d-m**, collects in the upper tank and the air of this tank goes out following the way **e-d-ţ-k**. The measuring cup contains sufficient wine to surpass the level **v** at the upper tank but not enough to reach the level **ţ** at the lower tank. So that the wine flows over the siphon **h-v-z** into the lower tank and the air from the lower tank passes to the upper tank through the pipe **d-e**.

When, after the end of the filling, water is poured little by little into the jar through the hole **a**, the air pressure formed by the water on the upper tank causes the outflow of the same quantity of wine from the lower tank through the pipe **ţ-ş-k** (see Motif 8). If water is poured abundantly through the hole **a**, since a part of the water flows through the pipe **c-b** into the funnel **l**, the same quantity of mixed wine and water pour out as water is poured in.

The block diagram of the system resembling the previous one is seen in Figure 55-b.

Model 56-A Jar With Two Outlets, Which After Being Filled by Wine and Water, Pours out the Wine and Water in an Alternating Manner With Predetermined Quantities Until it Gets Empty (Figure 56-a; as the original figure concerning this model is incomprehensive a reconstruction is given in Figure 56-b)

First, wine is poured gently into the jar through the sieve-like lid **ş**. The funnel which is controlled by the flowrate (see Motif 3) causes the collecting of the wine in tank **ţ**. Secondly, the water abundantly poured into the jar flows into the tank **c** which contains a floated tank. As long as the filling continues, or the tank **v** is full, the valves **c** and **ţ** are closed. When the filling ends the tank **v** empties through a hole, and with the rising of the float **e** in the tank **z**, the valves **c** and **ţ** open. Under the valves a two positional balance is placed (see Motif 6). First the wine of the tank **ţ** and the water of the tank **c** flow out following the ways **ţ-a-h-k-ş** and **c-b-d-s-f**. At the same time from the tank **a** on the left arm of the balance some quantity of wine flow along the pipe **l-m-y** into the tank **y** which is on the right arm of the balance. When the wine collecting in the tank **y** reaches a certain quantity the equilibrium of the balance changes and the arm inclines to right. In



filling
Q_g
UPPER TANK
H_1
SIPHON v-z
Q_{11}
LOWER TANK
H_2
tilting
Q_{21}
Q_{22}
overflow
water level
Q_{12}
wine
Q_{g1}
water
water+wine outflow
Q_{f1}
Q_{f2}
Q_f
outflow k

Figure 55–b

this position the wine of the tank ţ takes the way ţ-s-f and the water of the tank c takes the way c-k-ş, so that the liquids flow out changing their places. At the inclined position of the balance, the wine in the tank y, passes through the pipe y-n and following the way y-n-h-k-f goes out mixing to the outpouring wine of the tank ţ. When the tank y empties the balance returns to its first state and this operation repeats continuously as long as liquids exist in the tanks.

The block diagram of this system is given in Figure 56-c. For the separation of the liquids in different tanks a control by flowrate (Motif 3), to enable the outflow operation float controlled valves (Motif 5), and to change the outflow places of the liquids a two positional balance, (Motif 6) is used. In a modern sense this system operates like a two positional oscillating circuit (or like a astable multivibrator).

Model 57-A Jar With Two Outlets, in Which, Where the Liquid Has To Be Poured out, Can Be Determined by Hand (Figure 57-a)

The liquid is poured into the jar through the sieve-like lid **a**. It flows first into the tank **c** on the left arm of a balanced valve (see Motif 6) and from there overflowing the tank **c** flows to the upper tank formed by the partition **ţ-l**. As long as the tank **c** is full or the filling continues the balance which is inclined to the left closes the valve **v**. When the filling ends the tank **c** empties over a hole, the balance inclining to the right opens the valve **v**. The liquid collected at the upper tank flows now into a floated balance with two positions (see again Motif 6). Assuming that at the beginning the balance is inclined to the right, then the liquid takes the way **v-y-c-t-k** and flows out from the right outflow **k**. If one closes the outflow **k** by his hand, with the rising level of the liquid in the tank **f** the float **z** rises and the balance inclining to the left changes position. Now the liquid pouring through the valve **v**, taking the way **v-ţ-c-s̄-s** flows out from the left outflow s. The liquid which is collected in tank **f** when the outflow **k** is closed by hand, passes through the siphon **s-ạ** into the tank **ş** and mixes to the outflowing liquid pouring out from **s**. So that after a short time, when the outflow **k** is left free, nothing flows out from there. Similarly if one closes the outflow s by hand with the rising of the liquid level in tank **ş** the float **h** rises and the balance changes position inclining right again. The liquid begins

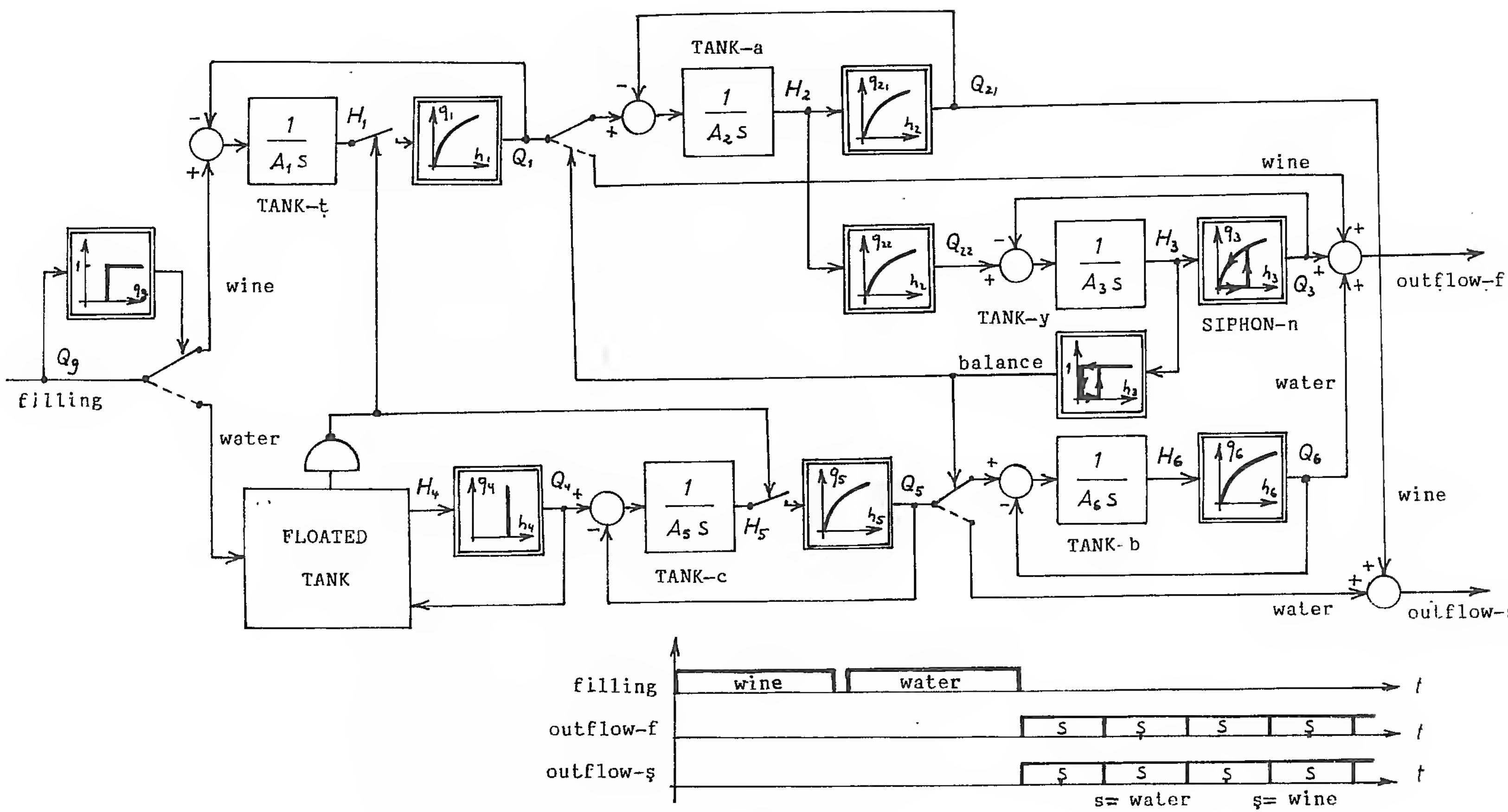

TANK-t
TANK-a
TANK-y
TANK-b
TANK-c
SIPHON-n
balance
FLOATED
TANK
filling
wine
water
outflow-f
outflow-ş
Q_g
H_1
Q_1
H_2
Q_{21}
Q_{22}
H_3
Q_3
H_4
Q_4
H_5
Q_5
H_6
Q_6
$\frac{1}{A_1 s}$
$\frac{1}{A_2 s}$
$\frac{1}{A_3 s}$
$\frac{1}{A_5 s}$
$\frac{1}{A_6 s}$
filling
outflow-f
outflow-ş
wine
water
s= water
ş= wine

Figure 56-c

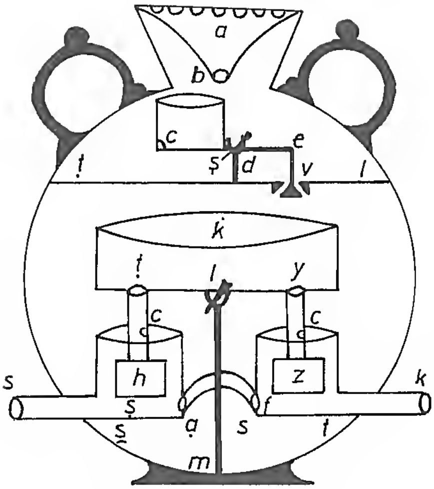


Figure 57—a (T)

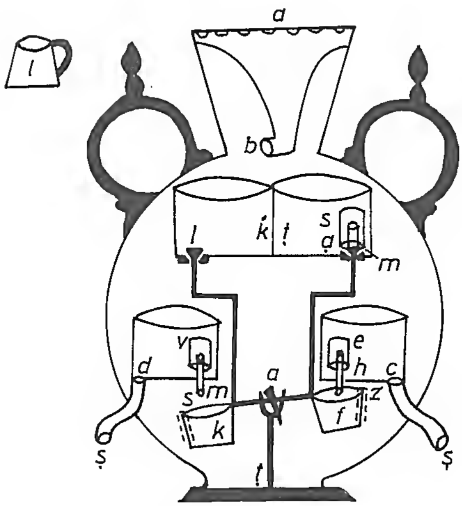


Figure 59—a (T)

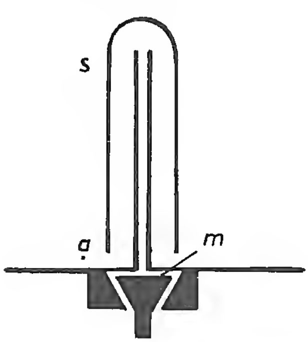


Figure 59—b

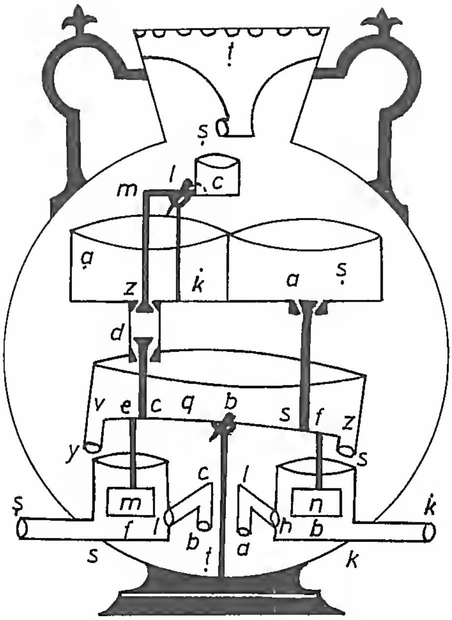


Figure 58-a (T)

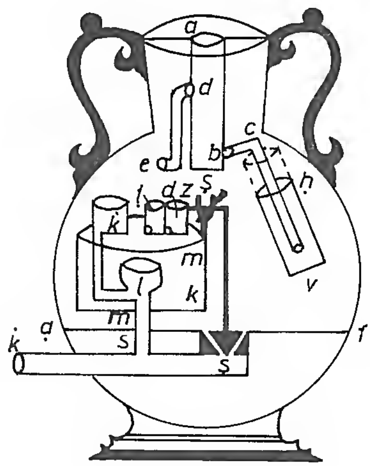


Figure 60—a (Ṫ)

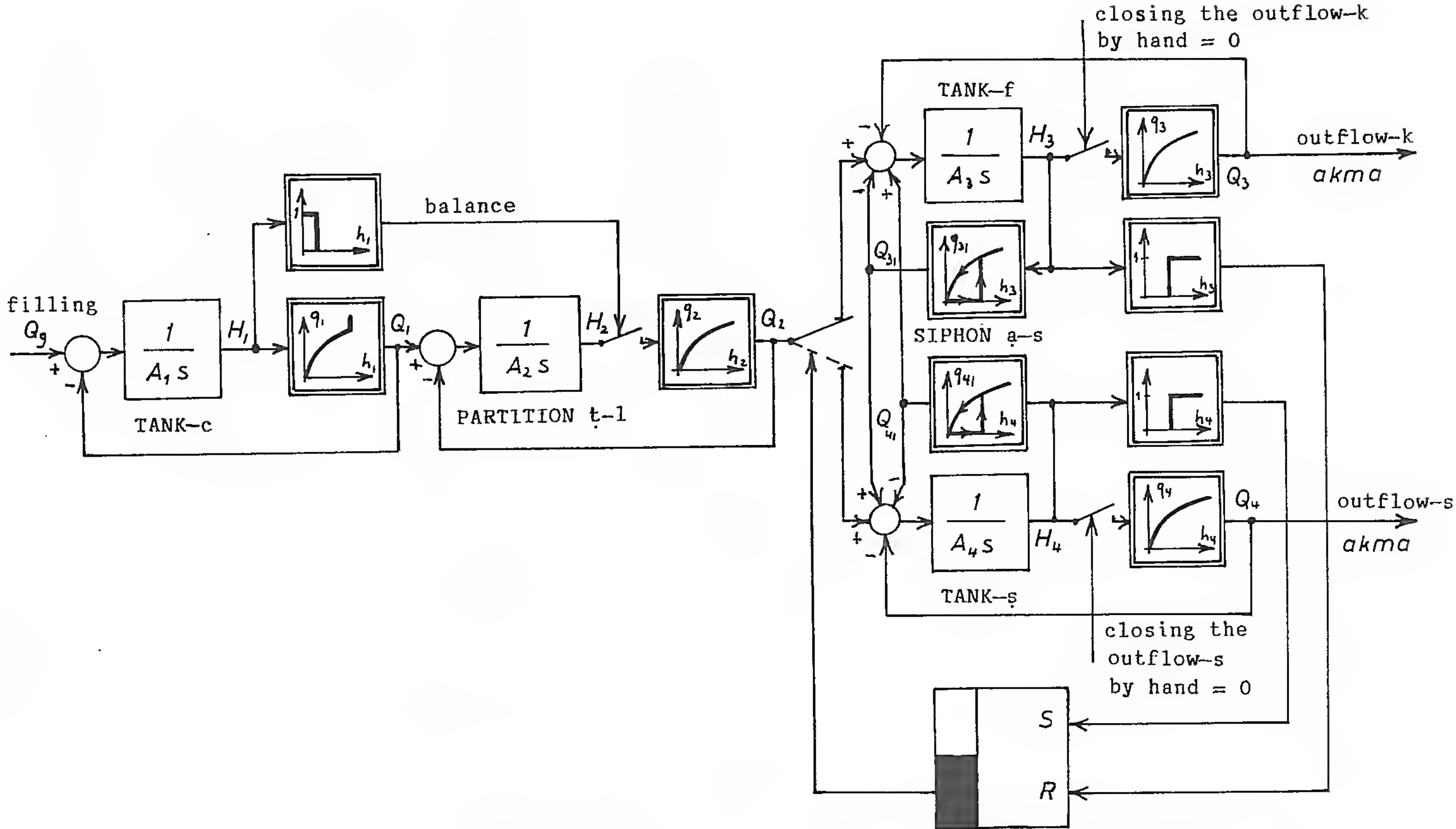


Figure 57-b

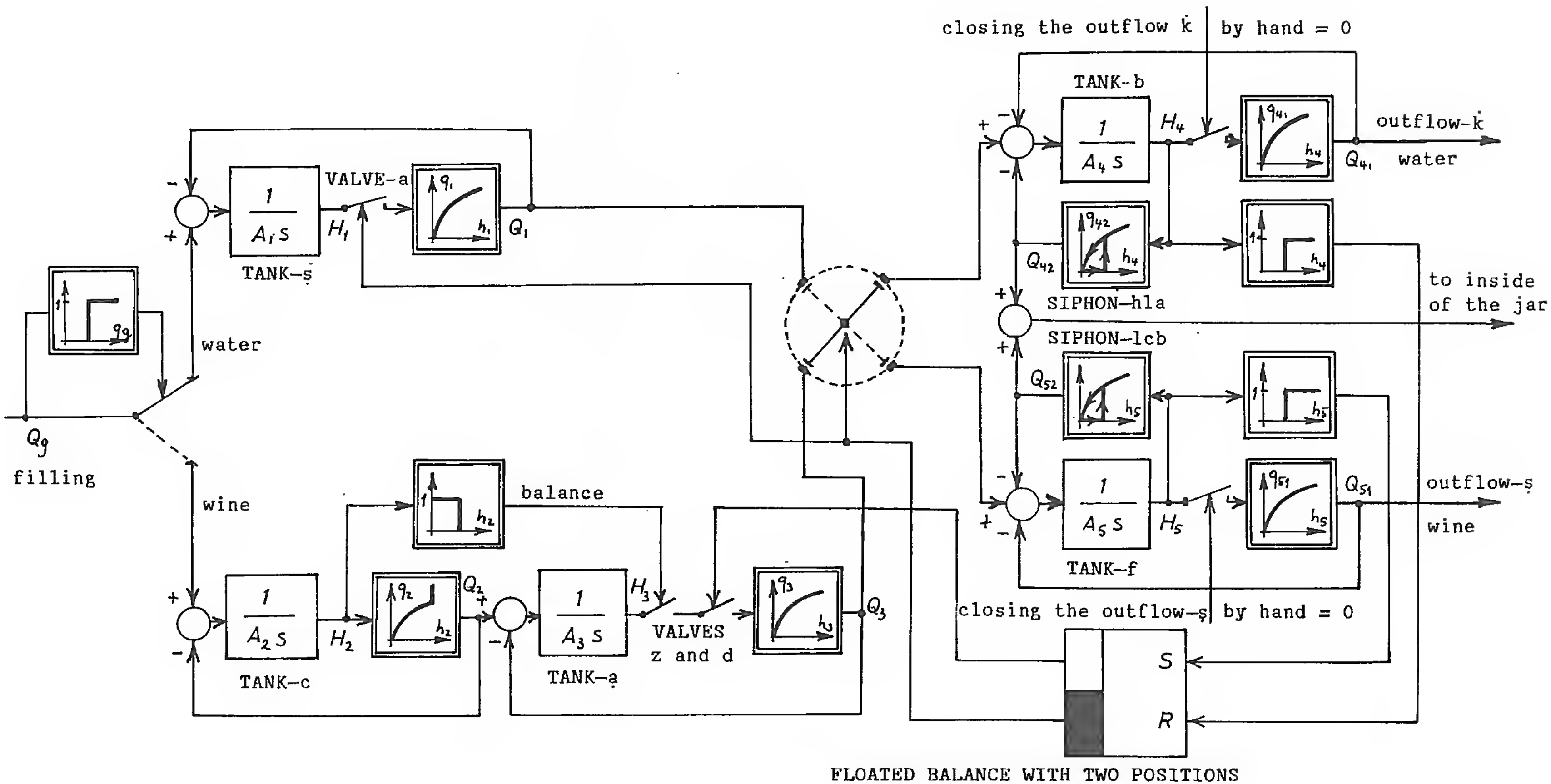
FLOATED BALANCE WITH TWO POSITIONS

to flow from the outflow k and the liquid of tank ş passes over the siphon ạ-s to the tank f. This operation can be repeated as long as there is liquid in the upper tank.

On the block diagram given in Figure 57-b, the floated balance with two positions is modelled by a S-R memory element. The trigerring signals for the memory element are obtained from the level of the liquid in the f and ş tanks. The system acts as a whole like and S-R memory element.

Model 58-A Jar With Two Outflows, Which After Being Filled by Water and Wine, Pours out the Last Filled in Wine From One Outflow, and When the Flow of Wine is Prevented by Hand it Pours out the First Filled in Water From the Other Outflow and So on (Figure 58-a)

First water is poured gently into the jar through the sieve like lid ţ. The water flows from the funnel ţ-ş (see Motif 3) into the tank ş which contains the valve **a**, closed at the beginning. When wine is poured abundantly into the jar it flows first into the tank **c** on the right arm of a balanced valve (see Motif 6) and from there into the tank **ạ**. As long as the tank **c** is full or the filling continues the valve **z** on the left arm of the balance is closed. When the filling ends the tank **c** empties through a hole on the bottom and the valve **z** opens. The wine of the tank ạ passes through the open valves **z** and **d**, over the base of the right inclined tank of the two positional floated balance (see Motif 6) ịnto the right tank **b**, and from there flows out through the outflow **ḳ**. If one closes the outflow **k̇** by hand, by the rising level of the wine collecting in the tank **b**, the float **n** rises and the two positioned balance inclining to the left changes position. With the change of the balance position, the valve **d** closes and the flow of the wine ends; now the valve **a** opens and the water of the tank ş, flowing over the base of the left inclined tank of the two positional floated balance to the left tank **f** goes out through the outflow **ş**. The wine which collects in tank **b** during the blocking by hand of the outflow **k̇** is absorbed by the siphon **h-l-a** into the jar.



closing the outflow k̇
by hand = 0
TANK-b
outflow-k̇
water
VALVE-a
TANK-ş
water
filling
wine
balance
to inside
of the jar
SIPHON-hla
SIPHON-lcb
outflow-ş
wine
TANK-f
TANK-c
VALVES
z and d
TANK-a
closing the outflow-ş
by hand = 0
S
R
FLOATED BALANCE WITH TWO POSITIONS

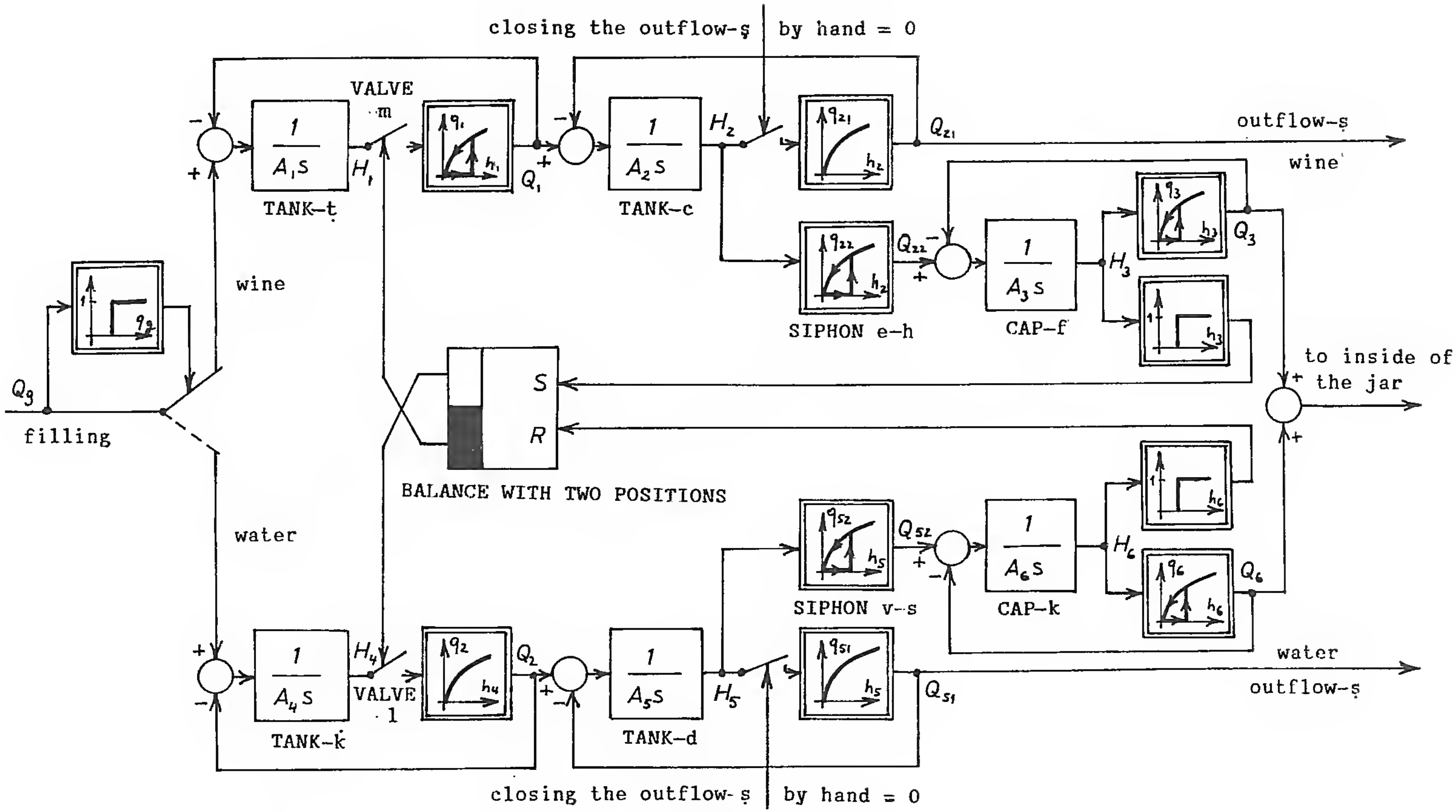
Figure 58-b

Now, if the flow of the water from the outflow ş is prevented by hand, by the collecting of water in tank **f** the float **m** rises, and the balance, changes its position again. The outflow of the water ceases, the water of the tank **f** is absorbed by the siphon **l-c-b** into the jar and wine begins to flow from the outflow **k**. This procedure continues till the liquids of tank ạ and ş are exhausted.

The block diagram of this system resembling the previous one (model 57) is given in Figure 58-b. Here, two different kinds of liquids are used, the separation is achieved by a flowrate control motif, the outflow place of the liquid is changed by the valves **a** and **d** tied to the floated balance, and the liquids remaining in the tanks **b** and **f** are conducted into the jar by the aid of the siphons.

Model 59-Another Jar With Two Outflows (see Model 58); **Which After Being Filled by Water and Wine Pours out the Last Inpoured Wine From One Outflow, and When the Outflow of Wine is Prevented by Hand it Pours out the First Inpoured Water From the Other Outflow, and So on** (Figure 59-a)

First, water is poured abundantly into the jar with a measuring cup **l** through the sieve-like lid **a**. The water flows from the funnel **a-b** into the tank **k** which contains a closed valve **l** on the bottom. The wine which is gently poured as the second gathers in the tank ţ (see Motif 3). The inpoured wine of the measuring cup **l** is just sufficient to operate the siphon **ạ-s** in the tank **ţ**. So that the wine flows from the open valve **m** (see the valve reconstruction in Figure 59-b) to the tank **c** and from there pours out from ş passing the pipe **c-ş**. If the outflow of the wine from ş is prevented by hand the level of the wine in tank **c** rises, and when the level **e** is reached, the siphon **e-h** begins to conduct. The wine absorbed by the siphon **e-h** from the tank **c** flows into the tank **f** on the right arm of a balance with two positions. When the tank **f** fills, the position of the balance changes, the arm inclining to the left, the valve **m** closes and the valve **l** opens. The pouring out of the wine from out flow ş ceases, by the opening of the valve **l**, the water from the tank **k** passes the tank **d** and pours out from the outflow **ş**. At the same time the wine of the tank **f** on the right arm of the balance flows into the jar through a siphon not shown in the original figure. If one prevents,



closing the outflow-ş
by hand = 0
VALVE
m
TANK-ţ
TANK-c
outflow-ş
wine
wine
filling
SIPHON e-h
CAP-f
to inside of the jar
S
R
BALANCE WITH TWO POSITIONS
water
SIPHON v-s
CAP-k
VALVE
1
TANK-k
TANK-d
water
outflow-ş
closing the outflow-ş
by hand = 0

Figure 59-c

also by hand, the flow of the water from the outflow ş, the water collecting in tank **d** flows over the siphon **v**-s into the tank **k** on the left arm of the balance with two positions. When the tank **k** gets full the balance changes position, the arm inclining to the left the valve **l** closes and the outflow of the water ceases. At the same moment the valve **m** opens and the wine begins to flow out again from the outflow ş. The water in the tank **k** on the left arm of the balance empties into the jar by a siphon also not shown in the original figure. This operation can be repeated till the tanks **ţ** and **k̇** become empty.

The block diagram of the system is given in Figure 59-c. The repeating of the model 58 by the help of different motifs prove the difficulties confronted in the realisation of the functions in the previous model. Especially in model 58 the fact that the rising of the floats in tanks **b** and **f** and the conducting of the siphons (Figure 58-a) at the same time causes some problems. In model 59 the changing of the balance position is achieved by the filling of the tanks **b** and **f**, but the filling and the emptying of these tanks are realised by siphons which are not effected by the movement of the balance.

Model 60-A Jar Which, After Being Filled With Wine, Pours out From its Free Outflow, As Requested Wine, Water or a Mixture of These Liquids Each Time When Water is Poured in (Figure 60-a)

First wine is poured continuously into the jar through the hole **a.** The wine following the way **a-d-b-c-v-ḫ** flows into the tank **ạ-f.** The valve ş is closed at the beginning. Since the way taken by the wine is formed like a double siphon (see Motif 2), the water poured into the jar after a short interval passes into the pipe **d-e**. The end of the pipe **d-e** must have three outflows as seen in the reconstruction figure 60-b. If the flowrate of the inpoured liquid is Q_g, with the validity of the property $K_1+K_2+K_3 = 1$, the flowrate of the liquid flowing out from the first outflow is given by K_1Q_g (in Figure 60-c it is assumed that the K_i coefficients change linearly with the flowrate Q_g).

Secondly when water is gently poured in, it flows from the pipe **d-e** into the tank **d** on the left arm of a two positional balance and from

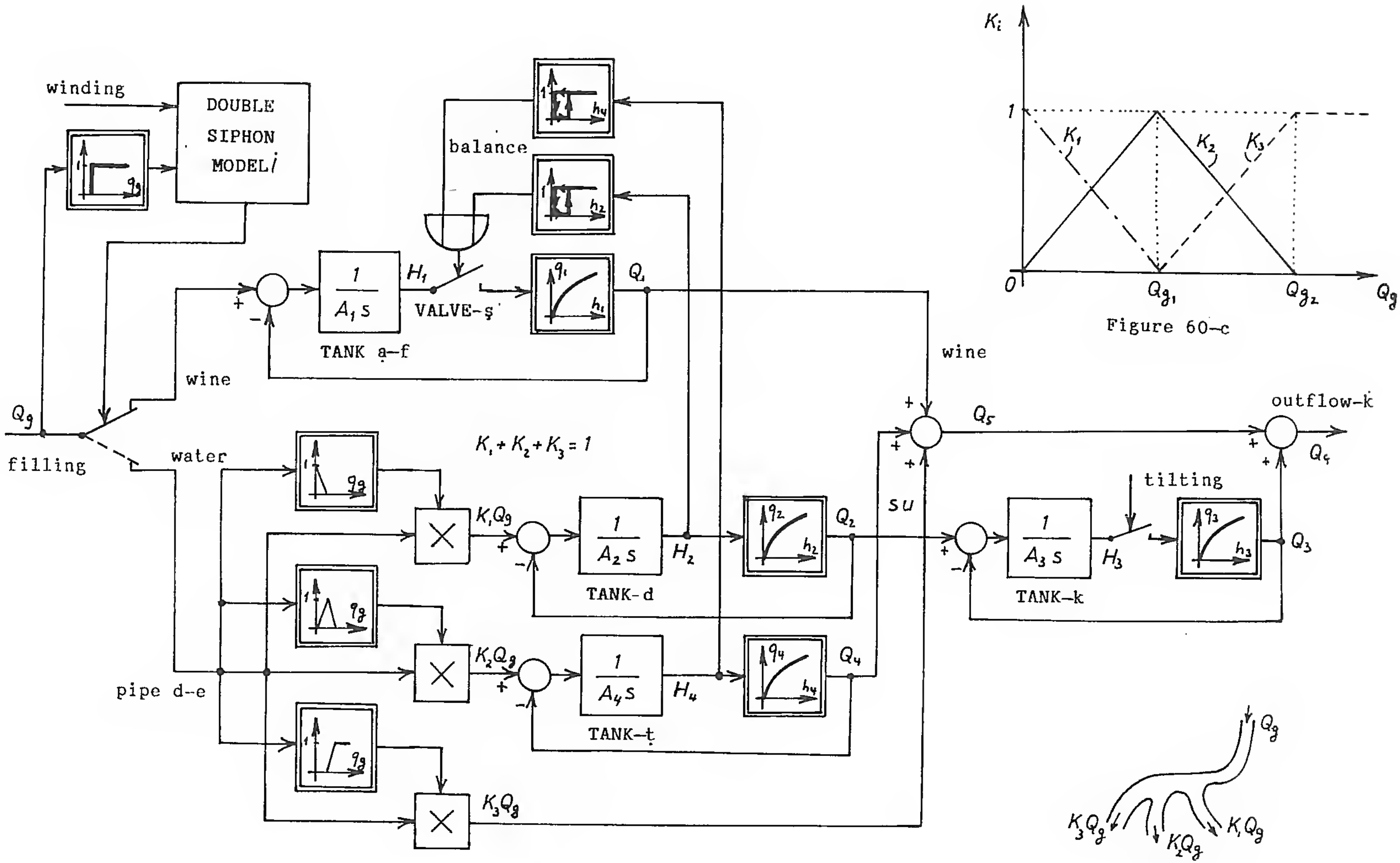


Figure 60–d

Figure 60–c

Figure 60-b

there it flows to the tank **k**. When the water level in tank **d** reaches a certain height the balance changes position, the arm inclining to the left the valve **ş** opens. Then the wine from the tank **ạ-f** flows out following the pipe **ş-k̇**. The outflowing of the wine continues as long as the tank **d** is full or the water is poured in gently. When the inpouring of the water is interrupted the tank **d** empties through the hole at the bottom, by the changing of the balance position the outflow of the wine ceases.

If the flowrate of the inpoured water is increased, a part of the liquid flows out from the middle outflow of the pipe **d-e** to the tank **ţ** which is also on the left arm of the balance adjacent to tank **d**. When the tank **ţ** fills, the equilibrium of the balance changes and inclining to the left the valve **ş** opens. The water outflowing from the tank **ţ** follows the way **l̇-m-s** and mixes with the wine coming from the valve **ş** and flows out from **k̇** as a water-wine mixture proportional to the flowrate of the water which is poured into the jar. When the inpouring is interrupted, tank **ţ** gets empty like tank **d** and the outflow ends. When water is abundantly poured into the jar through hole **a**, the water which flows out from pipe **e-d**, following the way **k̇-m-s-k̇** does not mix with wine, since valve **ş** stays closed. These operations can be repeated as long as wine exists in tank **ạ-f** and water is poured into the jar.

The block diagram of the system is given in Figure 60-d. The collecting of wine in tank **ạ-f** is realised by a double siphon motif (see Motif 2), the distribution of the water to the different tanks depending on the flowrate by a flowrate control motif (see Motif 3) and the mixing of the water with wine by using a balanced valve motif (see Motif 6). In the original figure the pipe **d-e** and the double siphon **b-c-v-ḫ** are drawn erroneously.

Model 61-A Jar Which After Filled With Wine, Pours out Water and Wine Alternately in Determined Quantities, Each Time Water is Also Poured in the Jar Continuously (Figure 61-a)

The wine poured continuously into the jar through the hole **k̇** flows into the upper tank containing a double siphon and an overflow pipe.

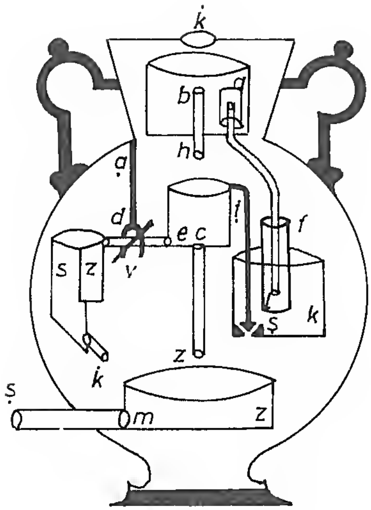


Figure 61—a (T)

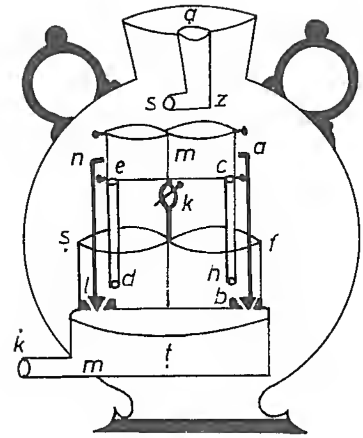


Figure 62—a (T)

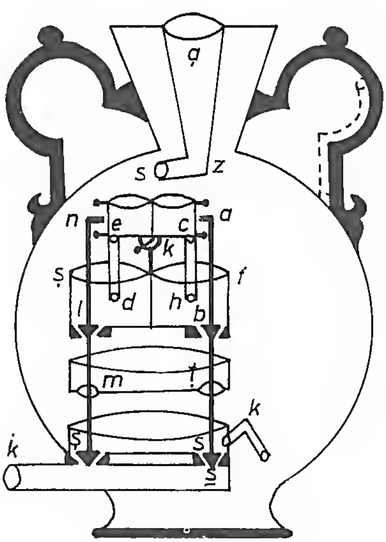


Figure 63—a (T)

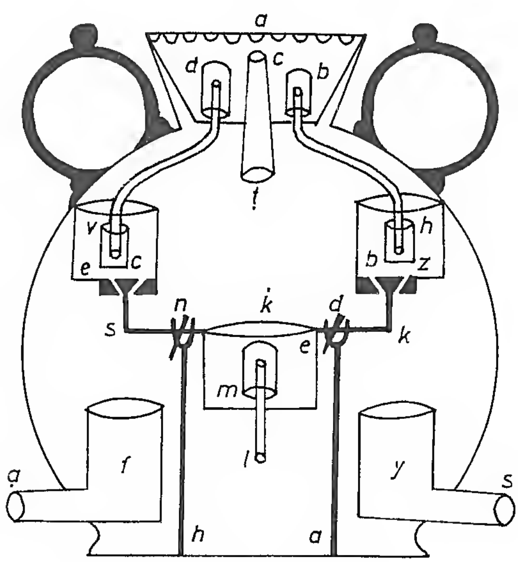


Figure 64—a (T)

Passing the double siphon **a-l-f-k** the wine collects in the tank **k** which contains the valve **ş** closed at the beginning. The water which is poured into the jar through the hole **ḳ** after a short interruption flows, since the double siphon is plugged, through the overflow pipe **b-h** into the tank **c** which is on the right arm of a two positional balance (see Motif 6). The water passing the pipe **c-z** at the bottom of tank **c** flows into tank **m-z** and pours out from the outflow **ş** as the first. Further a pipe **e-d**, prolonging along the balance arm, connects the tank **c** on the right arm of the balance to the tank **z** on the left arm of the balance. Thus, a quantity of water flows from tank **c** to tank **z** running along the pipe **e-d**. When the tank **z** fills, the equilibrium of the balance changes and inclines to the left. With the inclining of the balance, the water flows now into the jar, since the tank **c** is not under the pipe **b-h** anymore. Also by the opening of the valve **ş**, connected to the right arm of the balance, the wine begins to flow out from the outflow **ş**. The water of the tank **z** on the left arm of the balance flows first to the adjacent tank **s** and then over the pipe **ḳ** flows into the jar. When all of the water in tank **s** and **z** pours out, the balance returns to its first position. By the closing of the valve **ş** the outpouring of the wine ceases and the water flows out again following the way **b-h-c-z-m-ş**. This operation will repeat as long as the tank **k** containing, wine and water is poured in the jar.

The block diagram of the system is seen in Figure 61-b. The liquids are separated by a double siphon and the oscillation is realised by a balance with two positions. In a modern sense, this model, depending on an input signal (here the inpouring water), behaves like an oscillation circuit.

Model 62-A Jar Which After Being Filled With Wine, Pours out Wine From its Free Outflow Each Time When Water is Poured in and Water When Wine is Poured in (Figure 62-a)

First wine is poured abundantly into the jar through the hole **ạ**. The wine flows passing the funnel **ạ-z-s** (see Motif 3) into the tank **e** which is on the left arm of a three positioned balance (see Motif 8). The balance which lies horizontally when it is empty inclines to the left and the wine pouring into the tank **e** flows over the pipe **e-d** to the tank **d** containing the valve **d** which is closed at this position of the balance. If water is

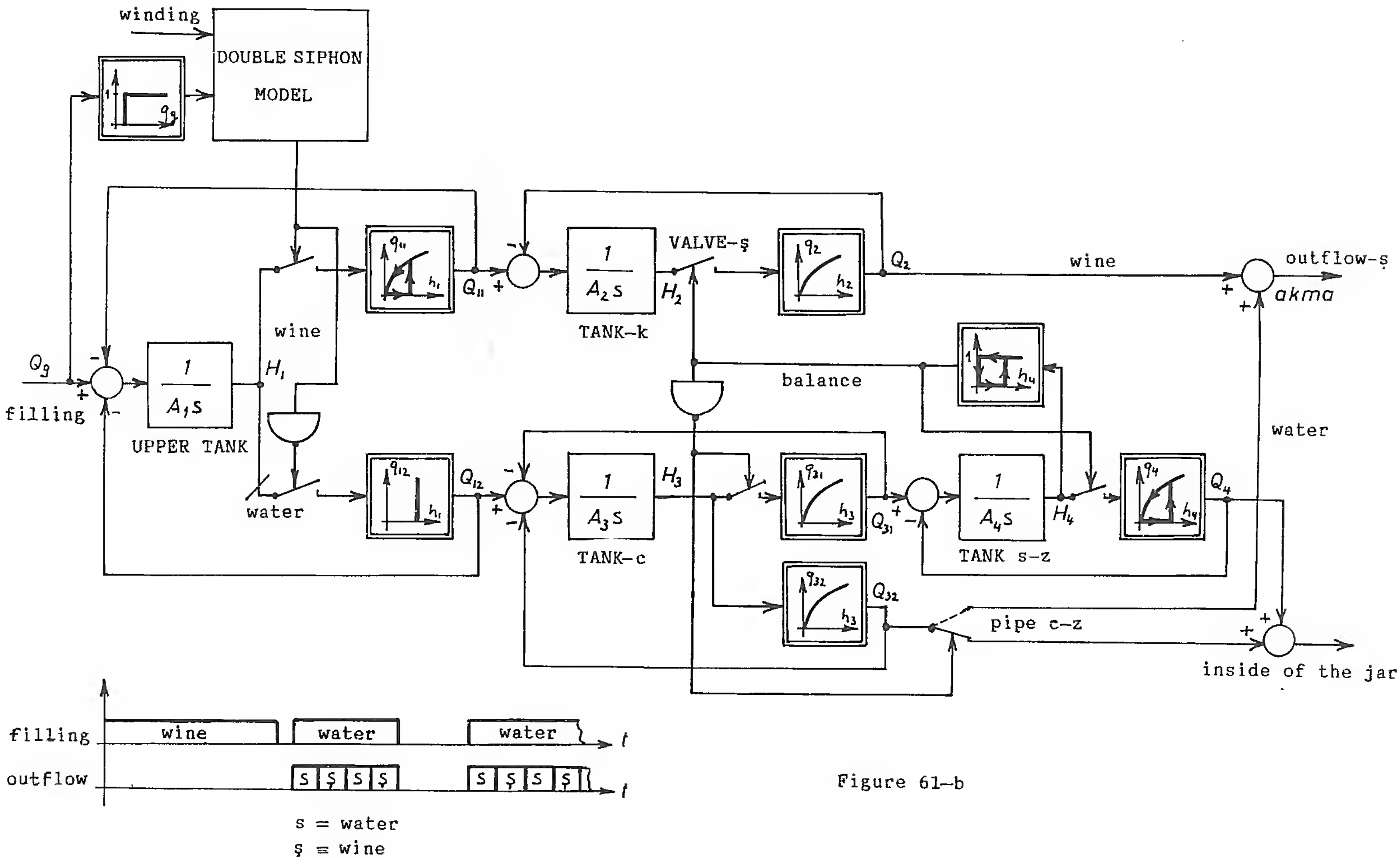

winding
DOUBLE SIPHON MODEL
Qg
filling
UPPER TANK
H1
wine
water
Q11
Q12
TANK-k
TANK-c
H2
H3
VALVE-ş
balance
Q2
Q31
Q32
TANK s-z
H4
Q4
wine
outflow-ş
akma
water
pipe c-z
inside of the jar
filling
outflow
wine
water
water
s ş s ş
s ş s ş
t
s = water
ş = wine

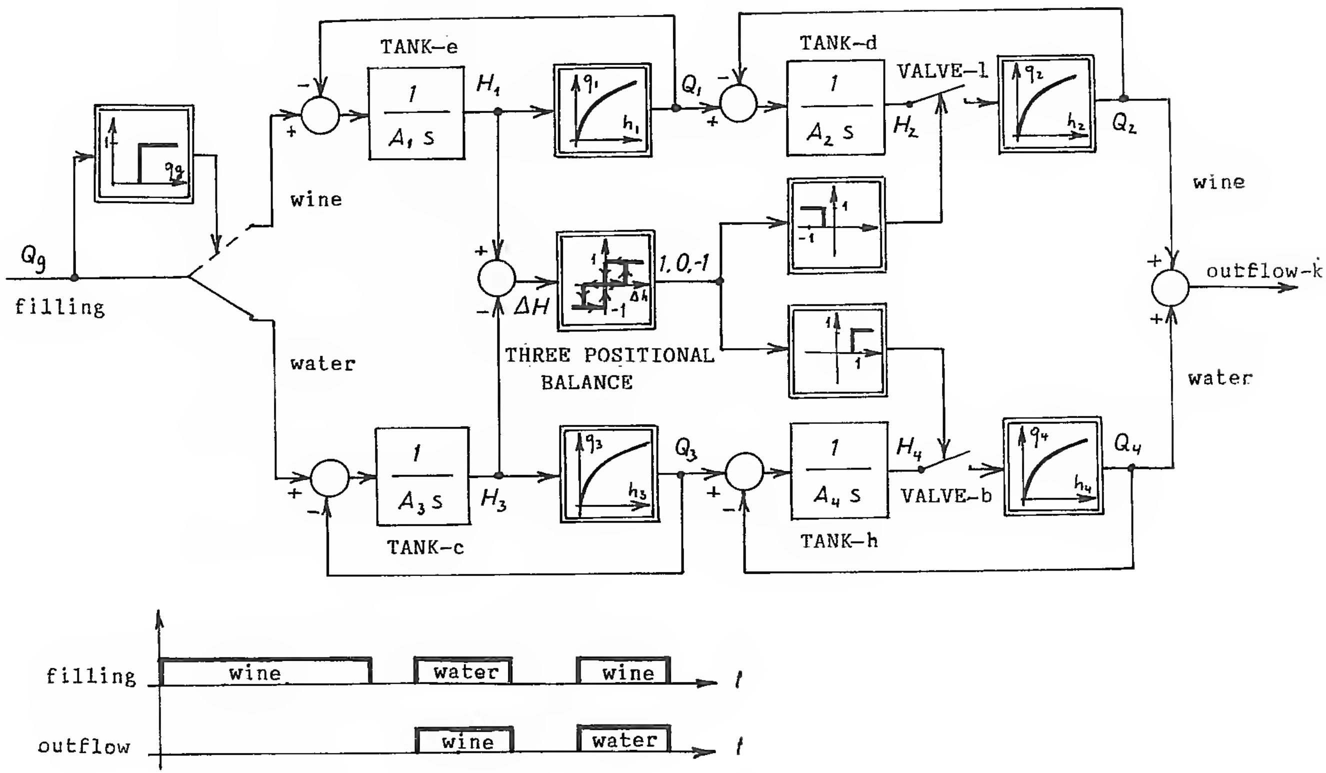
Figure 61-b

poured slowly into the jar through the hole ạ it flows into the tank c on the right arm of the balance. Then the balance inclines to the right and the valve ḷ opens. The wine flows out from the tank d following the way l-m-k and the water poured in tank c flows into the tank h passing the pipe c-h. If the inpouring is interrupted for a time, by the emptying of the tank c, the balance returns to its middle position and the outflow of the wine ceases. Thus, each time wine is poured in forcefully, by the left inclining of the balance, the valve b opens and water from tank h flows out; and each time water is poured in slowly, by the right inclining of the balance, the valve l opens and wine from tank d flows out. This operation can be repeated as many times as wine and water exist in tanks d and h.

The block diagram of the system is given in Figure 62-b. The horizontal middle (0), left (1) and right (-1) inclining states of the three positional balance is derived from the level difference $\triangle h = h_1 - h_3$ of the tanks e and c.

Model 63-A Jar With a Free Outflow Which Pours out (or if Desired Not) the First Inpoured Liquid When the Second Liquid is Poured in, the Second Inpoured Liquid When the Third Liquid is Poured in, and so on... (Figure 63-a)

This system resembles very much Model 62. The first forcefully poured liquid into the jar through the hole ạ flows from the funnel ạ-z-s into the tank e on the left arm of a three positioned balance (see Motif 8) and from there passing the pipe e-d collects at the tank d. As long as the first liquid flows in tank e and the tank is not empty the balance inclines to the left and the valve b opens but since the tank h is empty nothing flows out of the jar. After a short interval the second slowly poured liquid into the jar through the hole ạ flows from the funnel ạ-z-s into the tank c on the right arm of the three positional balance and from there passing the pipe c-h collects at the tank h. But the balance arm inclines to the right as long as the liquid flows through the tank c and the tank is not empty. The valves l and ş open the first liquid which is in tank d flows in the tank m-ţ and from there into the tank ş-s. Since the flowrate of the valve l is greater than the valve ş, the liquid flows immediately into the tank ş-s but pours out slowly from the



TANK-e
TANK-d
VALVE-1
wine
filling
water
THREE POSITIONAL
BALANCE
1,0,-1
TANK-c
TANK-h
VALVE-b
outflow-k
wine
water
filling
outflow
wine
water
wine
wine
water

Figure 62-b

outflow k̇. In the original Figure 63-a, a double siphon **s-k** is added to the tank **ş-s**. Although this siphon is not mentioned in the text, one can imagine that it was used in combination with an air control motif. Whenever the outflow of a liquid is not desired the air entrance (added on the handle of the jar) is closed. Each time the level reaches the upper end of the siphon **s-k** the liquid collected in tank **ş-s** is absorbed by the siphon into the jar. The third forcefully poured liquid into the jar through the hole **a̧** inclines the balance to the left and causes the outflow of the second liquid from tank **b**. This operation can be continued by inpouring the liquid slowly and forcefully. If desired the air entrance hole is closed and the liquid does not flow out.

The block diagram of the system is seen in Figure 63-b. In this diagram the block of the tank **ş-s** and the air control are added to the Model 62. The odd numbered liquids (forcefully poured in) collect in tank **d**, the even numbered liquids (slowly poured in) collect in tank **h**.

Model 64-A Jar With Two Outlets, When it is Filled by Wine and Water, Each Time a Wine-Water Mixture is Poured in, the Same Quantity of Wine Discharges From One Outlet and the Same Quantity of Water From the Other Outlet ("Separate the Mixing"!) (Figure 64-a)

The water poured into the jar through the sieve-like plate **a** flows into the upper tank containing two double siphons and an overflow pipe (see Motif 2). As the level **b** is lower than **d** and **c**, the inpoured water flows into the tank **h**, passing through the double siphon **b-h**. At the beginning the valves **b-z** and **e-c** are closed. The wine which is poured secondly into the jar after a short interruption flows into the tank **v**, since the level **d** is lower than **c** and the double siphon **b-h** is plugged. After the end of the filling, a wine-water mixture is poured into the jar through the plate **a**. Since the double siphons **b-h** and **d-v** in the upper tank are plugged, the wine-water mixture flows through the overflow pipe **c-ţ** into the tank **k̇** which is on a balance with two positions (see Motif 6). When the level of the wine-water mixture reaches a certain level in the tank **k̇** the equilibrium of the balance changes, rotating around the axle **s-n̩-d-k** the valves **e-c** and **b-z** open. The water of the tank **h** following the way **y-s** begins to flow out from the outflow s and

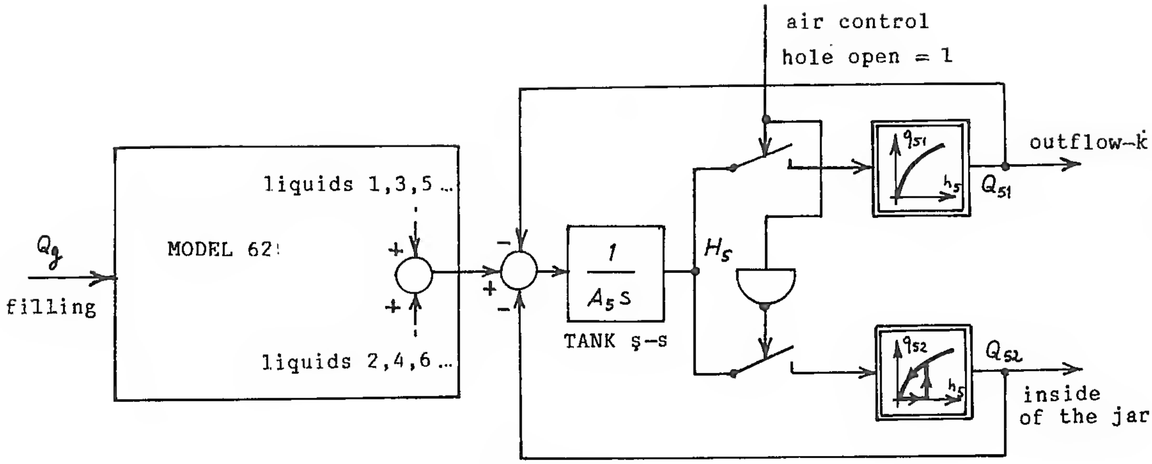


Figure 63-b

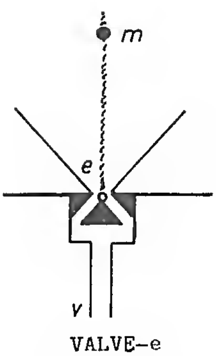


Figure 65-b

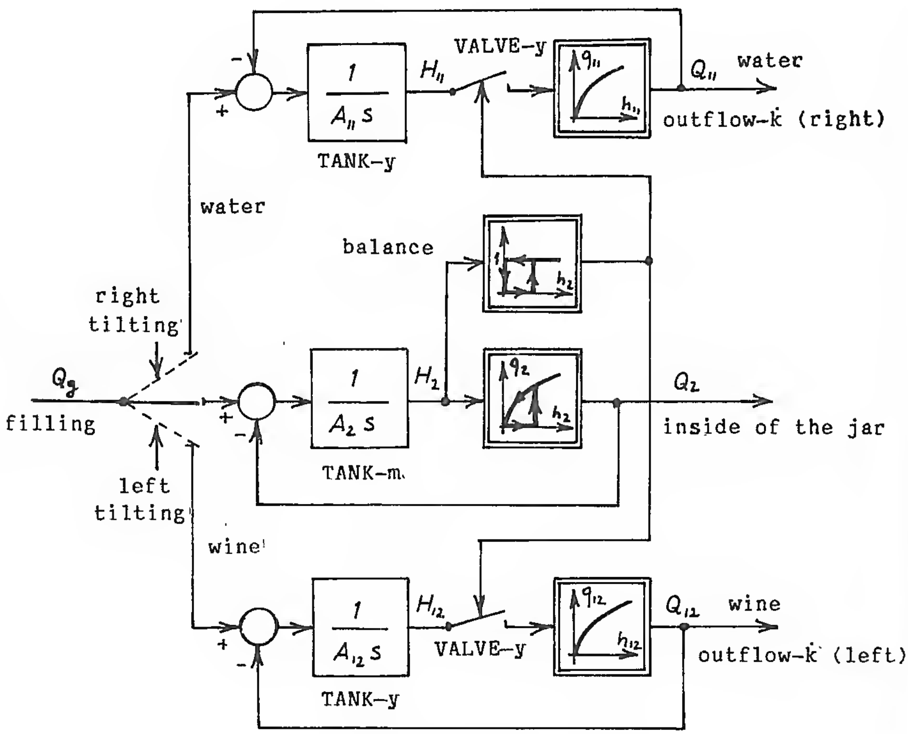


Figure 65-c

the wine of the tank v following the way f-ạ flows out from the outflow ạ. When the level of the wine-water mixture in tank k̇ reaches the upper point of the siphon m the liquid begins to discharge into the jar. When the inpouring of the mixture into the jar is interrupted the siphon m-l empties the tank k̇. The balance returning to its first state closes the valves e-c and b-z and the outflow of the wine and water stops. This operation can be repeated as long as there is water and wine in the tanks h and v.

The block diagram of the system is seen in Figure 64-b. The liquids are conducted to different tanks by the aid of two double siphons and an overflow pipe motif. To pour out the same quantity of water and wine as the inpoured mixture, a two positional balance carrying tanks is used. But to let the siphon m-l work the quantity of the water-wine mixture has to be sufficient.

Model 65-Another Jar (see Motif 64) With Two Outlets Filled by Wine and Water Which Tilted Does Not Pour out and Give Any Sound of Liquid; Each Time When a Wine-Water Mixture is Poured in, the Same Quantity of Wine Discharges From One Outlet and the Same Quantity of Water From the Other Outlet (Figure 65-a)

There is a moving funnel c-d under the sieve like plate which can rotate around an axle. Water is filled through the lid a when the jar is tilted to the right. The water flows through the right inclined funnel c-d into the gathering funnel over the valve e (in the original figure the gathering funnel is not drawn, a reconstruction of valve e is given in Figure 65-b). When the water enters the tank y by the valve e the air goes out through the valve z. Similarly wine is filled through the lid a when the jar is tilted to the left and this wine flows in the left side tank y. After the right and left side tanks y are completely filled, when the jar is swung, no sound of liquid can be heard. Since the valves e and z hang on the upper part of the jar together with the weights l and m, when the jar is tilted the valves e and z close and the liquids don't pour out. For this reason someone who examines the jar from the outside believes it to be empty.

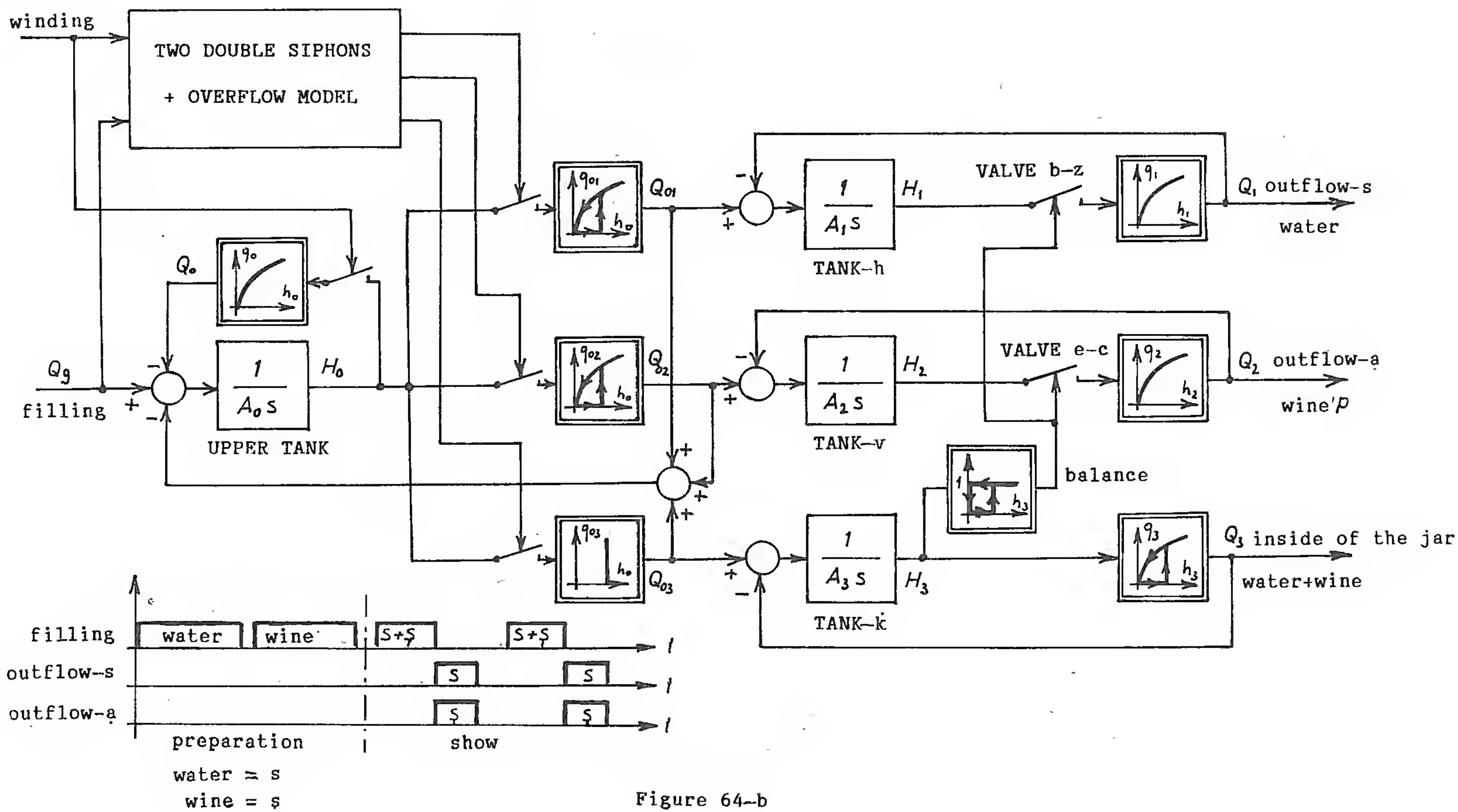

winding
TWO DOUBLE SIPHONS
+ OVERFLOW MODEL
Qg
filling
UPPER TANK
Q0
H0
Q01
Q02
Q03
TANK-h
TANK-v
TANK-k
H1
H2
H3
VALVE b-z
VALVE e-c
balance
Q1 outflow-s
water
Q2 outflow-a
wine
Q3 inside of the jar
water+wine
filling
outflow-s
outflow-a
water
wine
preparation
show
water = s
wine = ş

Figure 64-b

The wine-water mixture is poured into the jar at his normal position through the lid **a**. The liquid following the way **a-b-c-d** flows in the tank **m** which is on a balance with two positions. As in Model 64 when in tank **m** the level reaches a certain height, the equilibrium of the balance changes turning around the axle **l-ş-ş-l**. By the opening of the right and left valves **y**, water begins to flow out from the right and wine from the left outflow **k**.. The wine-water mixture of the tank **m** is absorbed into the jar by the siphon **h**. If the inpouring is interrupted, the tank **m** empties, the balance returns to its first position, the valves **y** close and the outpouring of the liquids from the outflows **k** ceases. This operation can be repeated as long as liquids are in tanks **y**.

The block diagram of the system is given in Figure 65-c. In order to have the siphon **h** working the wine-water mixture has to be sufficient.

Model 66-A Jar With Two Taps Filled by Water and Wine Which Pours out From One Tap Water and From the Other Wine, As Long As One Tap is Closed the Kind of the Outpouring Liquid on the Other Tap Changes (Figure 66-a)

First water is poured gently into the jar through the sieve like lid **b**. Then the water flows from the funnel **a** in the tank **ţ**. Some of the water flows through the open valve **l** from tank **ţ** to tank **a** following the way **c-h**. The tap **ţ** being closed the float **ş** rises with the mounting level of tank **a** and the valve **m** closes. When the level of the water in tank **a** reaches the hole **ş**, the water overflows to the tank **b** and since the tap **k** is also closed the level of the tank **b** rises. When tank **b** fills, by the rising of the float s the valve **l** also closes.

The second liquid, wine, is poured abundantly through the lid **b**. The wine flows from the funnel **a** in the tank **k**. Since the tank **a** is full, the valve **m** is closed. When the taps **ţ** and **k** are both open the water flows out from tap **ţ** following the way **ţ-l-c-h-a-ţ** and the wine from the tap **k** following the way **k-m-d-v-b-k**. If for example tap **k** is closed and tap **ţ** opened the level of the wine and the float s in tank **b** rise. When the valve **l** closes, wine begins to flow out instead of water from tap **ţ**, following the way **k-m-d-v-ş-a-ţ**. Similarly if tap **ţ** is closed and tap **k** opened water begins to flow out following the way

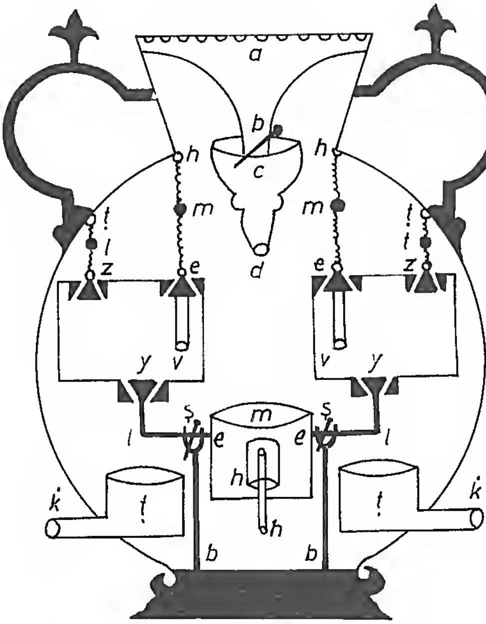


Figure 65-a (T)

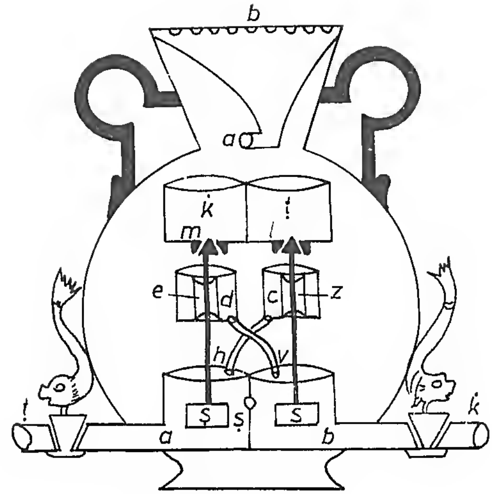


Figure 66-a (T)

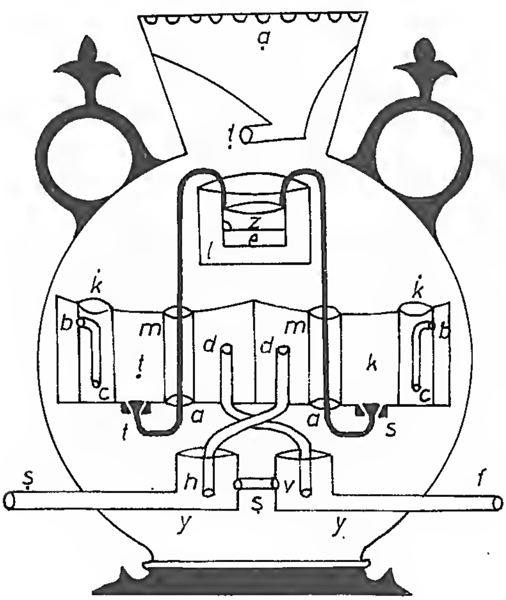


Figure 67-a (T)

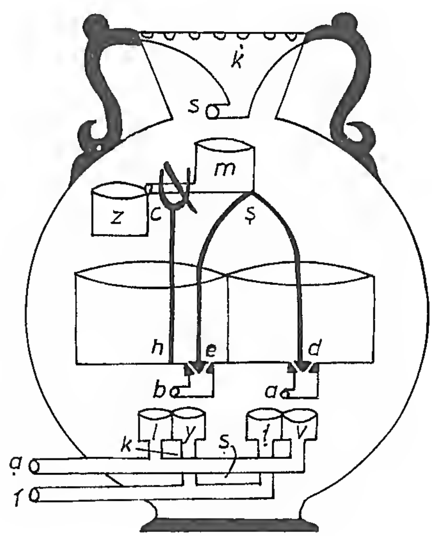


Figure 68-a (T)

ṭ-l-c-h-ş-b-k̇. When both taps are reopened, the system returns to its first state. This operation continues as long as the tanks k̇ and ṭ contain liquids.

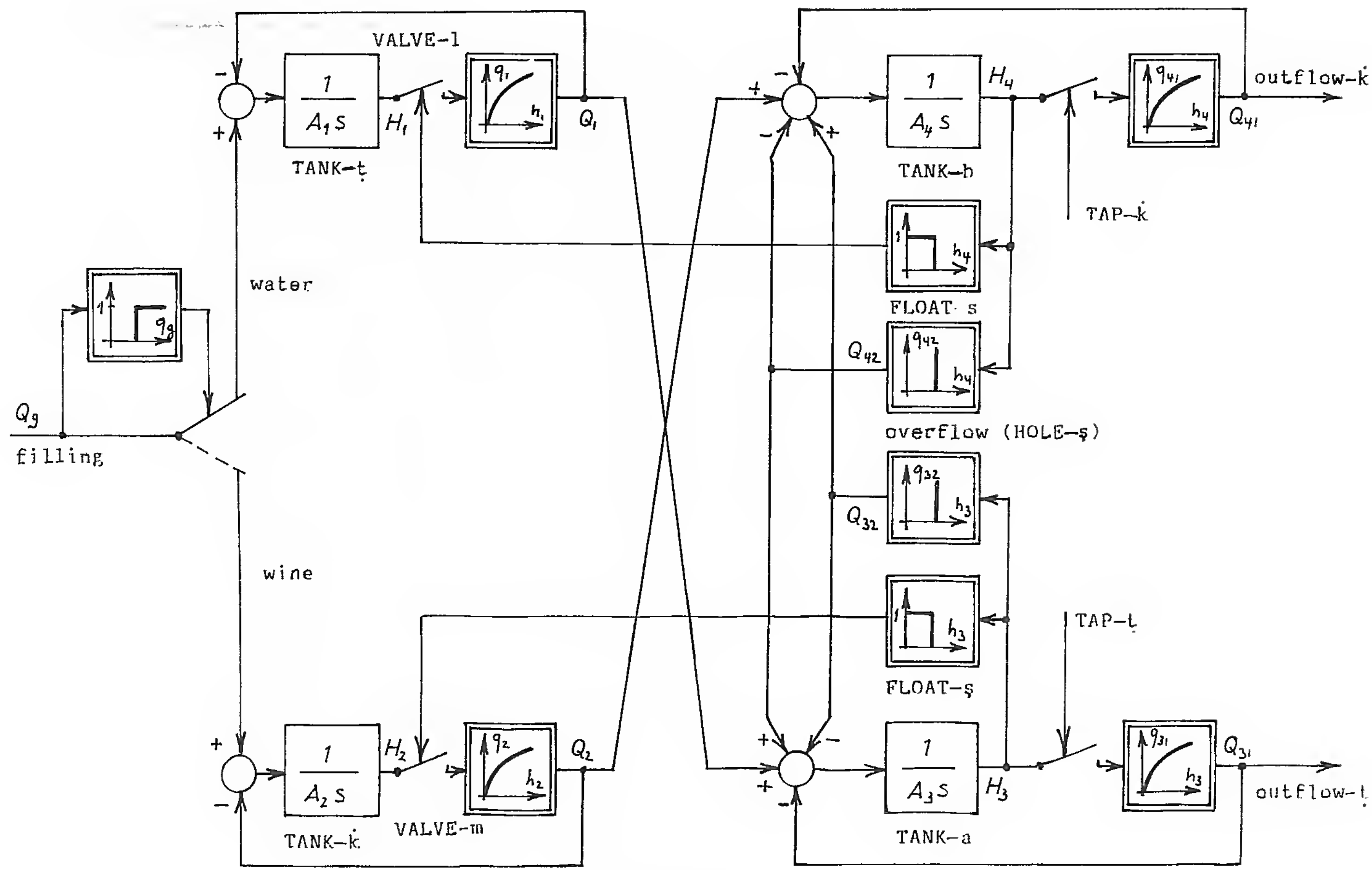
The block diagram of the system is given in Figure 66-b. The liquids are filled in tanks ṭ and k̇ by a flowrate control motif (see Motif 3), the outflow of the liquids is controlled by a two floated valve and an overflow hole.

Model 67-A Jar With Two Free Outflows, Filled by Water and Wine, Which Pours Water From One Outflow and Wine From the Other; When One of the Outflows is Closed by Hand the Nature of the Outpouring Liquid at the Other Outflow Changes (Figure 67-a)

First water is poured gently into the jar through the sieve-like lid **ạ**. The water flows from the funnel **ṭ** over the right side tank **k̇** (in the figure the end **ṭ** of the funnel is drawn too much to the left over the tank **l**). The water flows through the air obstacle **k̇-c-b** into the tank **k**. The air in the tank goes out by way of the pipe **d-h**.

Secondly, wine is poured forcefully into the jar through the lid **ạ**. The wine flows from the funnel **ṭ** into the tank **l** containing a floated tank and from there overflows over the left side tank **ṭ**. As long as the tank **z** over the float **e** is full or the forceful and continuous filling process of wine continues, the float **e** cannot rise and the valves **t** and **s** stay closed. The wine pouring over the tank **ṭ** flows through the air obstacle **k̇-c-b** into the tank **ṭ** and the air of the tank **ṭ** goes out from the pipe **d-v**.

After the continuous filling of the wine ends, and the tank **z** discharges, the float **e** rises and the valves **t** and **s** open. The water of tank **k** flows out from the outflow **f** and the wine of tank **ṭ** flows out from the outflow **ş** (in the Figure the valves **t** and **s** have erroneously not been drawn over the tanks **h** and **v**). The air enters the tank **k** over the pipe **h-d** and to the tank **ṭ** over the pipe **v-d**. If, for example, the outflow **f** is closed by hand the level of the water in tank **v** rises. When the level of the water reaches the **v** end of the pipe **v-d**, the air entrance of the tank **ṭ** being interrupted, the outflow of the wine ceases. Apart from this



VALVE-1
TANK-ţ
water
filling
wine
TANK-k̇
VALVE-m
TANK-b
TAP-k̇
outflow-k̇
FLOAT s
overflow (HOLE-ş)
FLOAT-ş
TAP-ţ
TANK-a
outflow-ţ

Figure 66-b

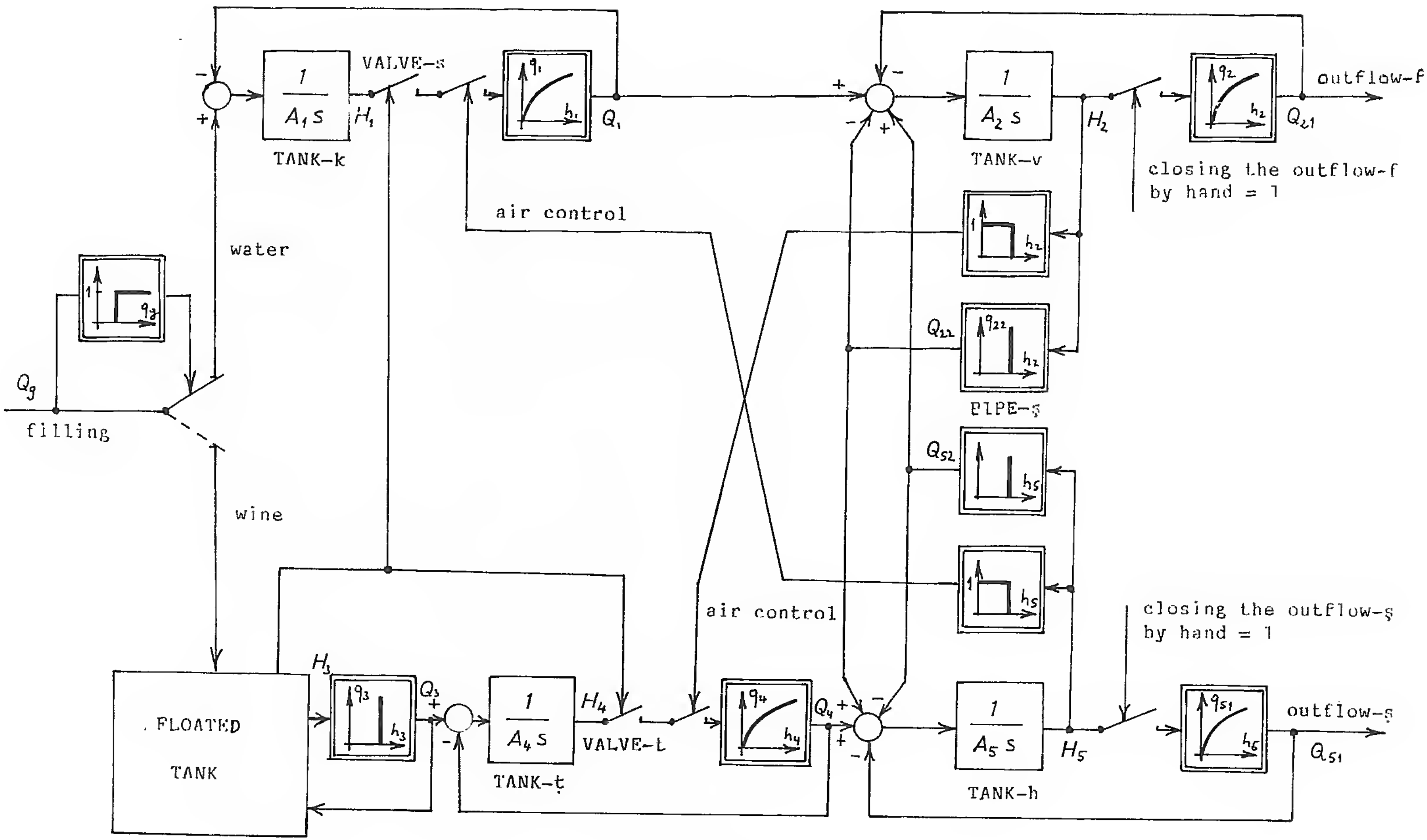
the water in tank **v** flows over the pipe **ş** into the tank **h** and pours out from the outflow **ş**. If the outflow **f** is taken free but the outflow **ş** is closed by hand, the air entrance of the tank **k** over the pipe **h-d** being prevented, the outflow of the water ceases and the wine passing the pipe **ş** begins to flow out from the outflow **f**. This operation continues as long as liquids are present in tanks **ţ** and **k**.

The block diagram of the system resembling Model 66 is seen in Figure 67-b. The effect is started by a floated tank motif (see Motif 5); changing the outpouring places of the liquids is realised by air obstacle and air control motifs (see Motif 7).

Model 68-A Jar With Two Free Outflows, Filled by Equal Quantities of Wine and Water Which Pours out The First Half of the Liquids From Different Outflows and the Second Half From Changed Outflows (Figure 68-a)

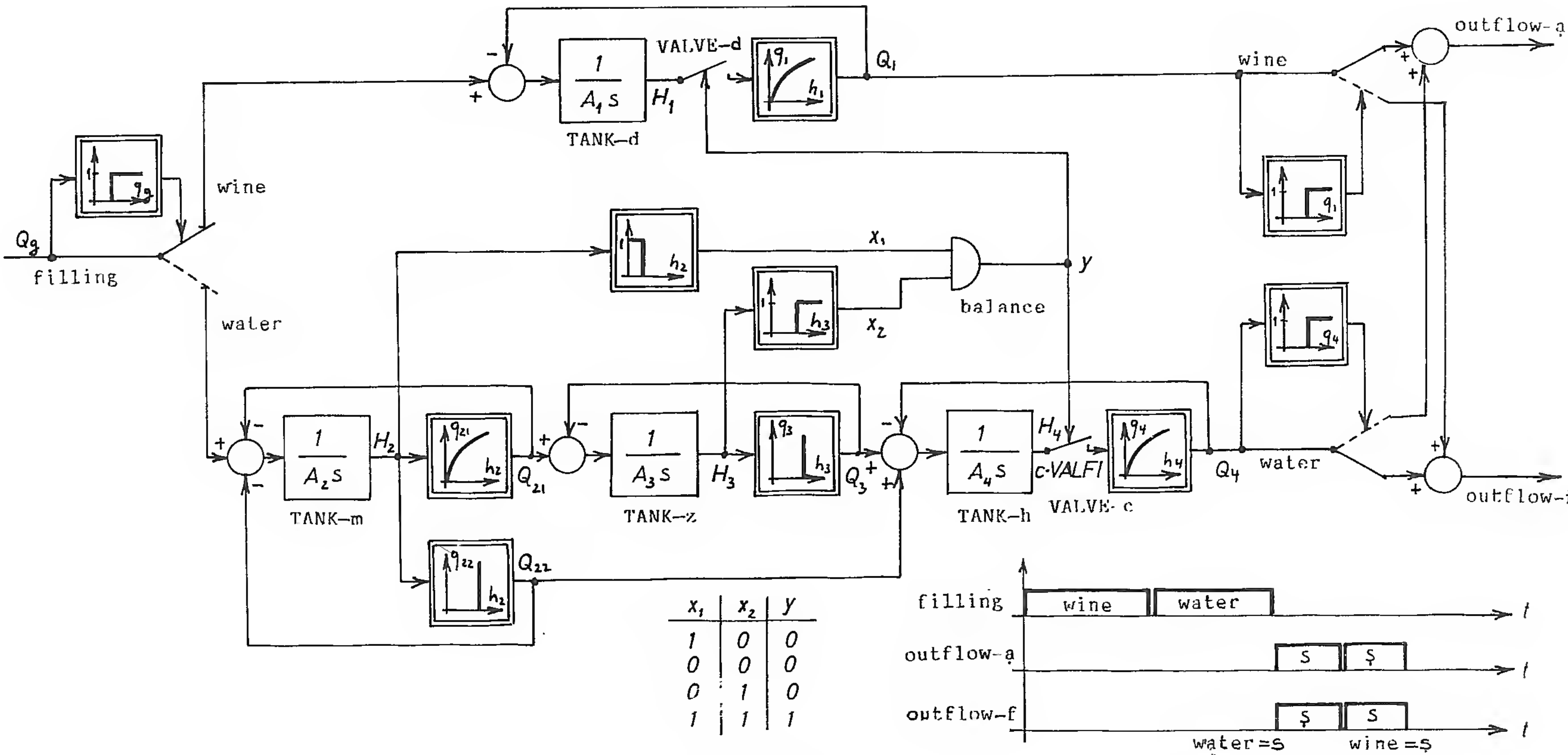
First wine is poured gently into the jar through the sieve like lid **k̇**. The wine flows from the funnel **k̇-s** in tank **d** (in the Figure the extremity s of the funnel is drawn too much to the left). Secondly, the same quantity of water is poured forcefully into the jar through the lid **k̇**. The water flows from the funnel **s** into the tank **m** which is on the right arm of a balance with two positions (see Motif 6). As long as the tanks **z** and **m** are empty or only the tank **m** is full the balance is inclined to right. The water pouring into the tank **m** flows through the pipe **m-c** lying along the arm of the balance into the tank **z** and when this tank is full overflows into the tank **h**. When the forceful and continuous filling of the water ends the tank **m** empties, the balance equilibrium changes and with the inclining of the arm to the left the valves **e** and **d** open. At the beginning, when the levels of wine and water in the tanks **d-h** are high, the first half of the tank contents flows into the tanks **ţ** and **l**, the second half into the tanks **v** and **y**. So that, from the outflow **ạ**, first water then wine, and from the outflow **f**, first wine then water pour out.

The block diagram of the system is given in Figure 68-b. The in and outflow of the liquids are controlled by flowrate control (see Motif 3). The outflow is started by a balance with two positions (see Motif 6).



VALVE-s
TANK-k
water
filling
wine
FLOATED
TANK
air control
TANK-v
closing the outflow-f
by hand = 1
outflow-f
PIPE-ş
air control
VALVE-t
TANK-ţ
TANK-h
closing the outflow-ş
by hand = 1
outflow-ş

Figure 67-b



x_1	x_2	y
1	0	0
0	0	0
0	1	0
1	1	1

F.gure 68-b·

In order to have the valves **e** and **b** to be open ($y=1$), the tank **m** has to be empty ($x_1=1$) and the tank **z** full ($x_2=1$).

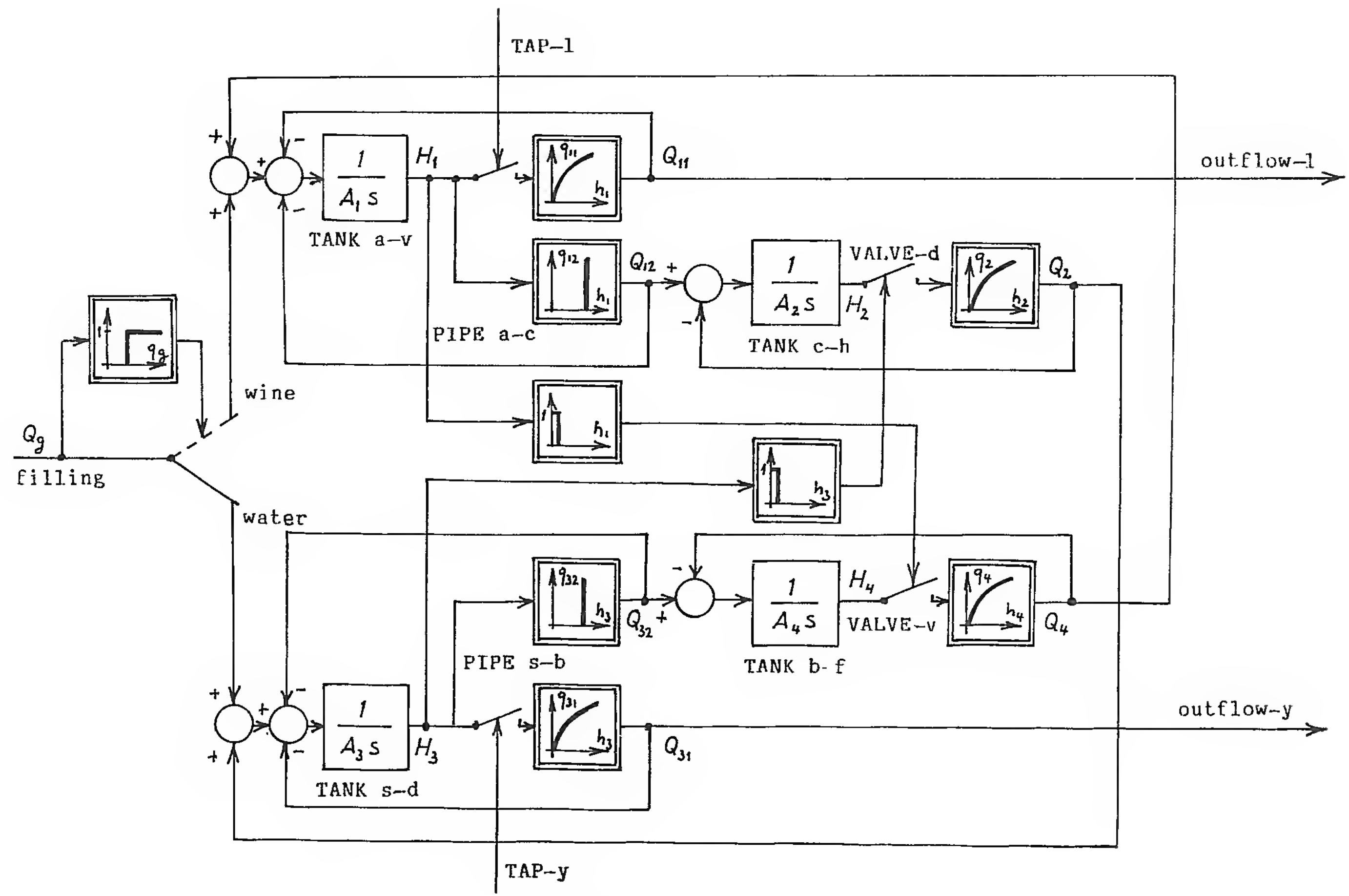
Model 69-Another Jar (see Model 68) **With Two Taps, Filled by Equal Quantities of Wine and Water Which Pours out the First Half of the Liquids From Different Outflows and the Second Half From Changed Outflows** (Figure 69-a)

The wine which is poured forcefully into the jar through the sieve like lid **ṭ** flows from the funnel **ṭ-k̇** (see Motif 3) into the tank **a-v** (in the figure the extremity **k̇** of the funnel is drawn far left). Since the tap **l** is closed, the wine collects in tank **a-v** and first by raising the float **z** closes the valve **v**. When the level of the wine in tank **a-v** reaches to **a**, it begins to flow passing the pipe **a-c** into the tank **c-h** and from there following the pipe **h-d** into the tanks **s-d**. The tap **y** being also closed, the wine level in tank **s-d** rises with the float **e** and closes the valve **d**. The wine is poured into the jar until the tank **c-h** is full.

The water which is poured gently into the jar through the lid **ṭ** flows in tank **s-d** and mixes with the wine which comes in first through the valve **d**. When the level of the water in tank **s-d** reaches **s** the water flows also over the pipe **s-ḃ** into the tank **b-f** and fills it since the valve **v** at the bottom of this tank is closed.

After filling when the taps **l** and **y** are opened first through the outflow **l** the wine from tank **a-v** and through the outflow **y** the water from the tank **s-d** flows out. When the tanks **a-v** and **s-d** get empty, the valves **v** and **d** open, and secondly through the outflow **l** the water from tank **b-f** and through the outflow **y** the wine from the tank **c-h** flow out until exhausting.

The block diagram of the system is given in Figure 69-b. Searching a new solution to the problem of system 68 shows that the first solution has not been satisfactory. The simplicity of the second solution should be considered.



TAP-1
outflow-1
TANK a-v
PIPE a-c
TANK c-h
VALVE-d
wine
filling
water
PIPE s-b
TANK b- f
VALVE-v
TANK s-d
outflow-y
TAP-y

Figure 69-b

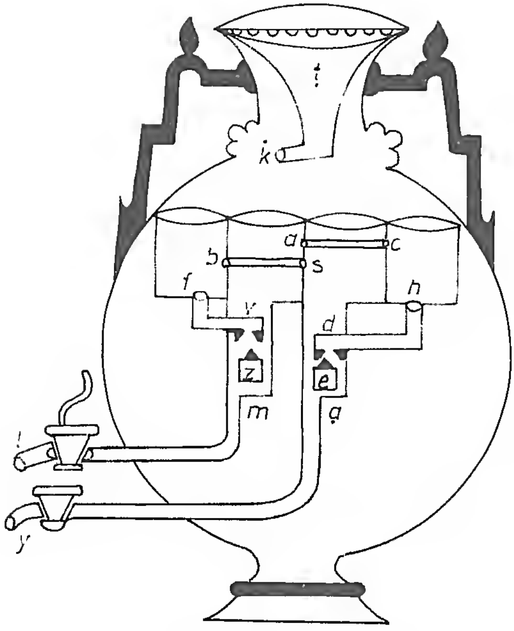


Figure 69–a (T)

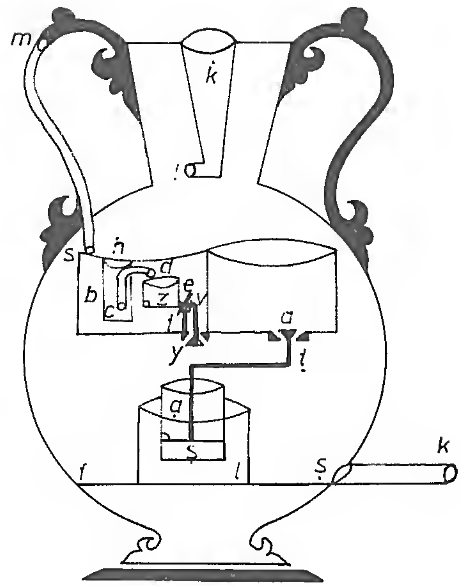


Figure 70–a (T)

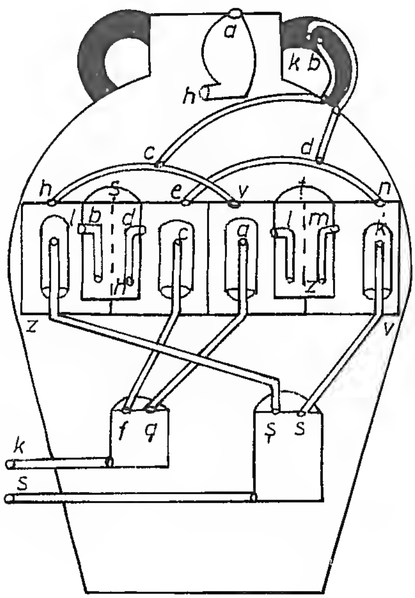


Figure 71–a (V)

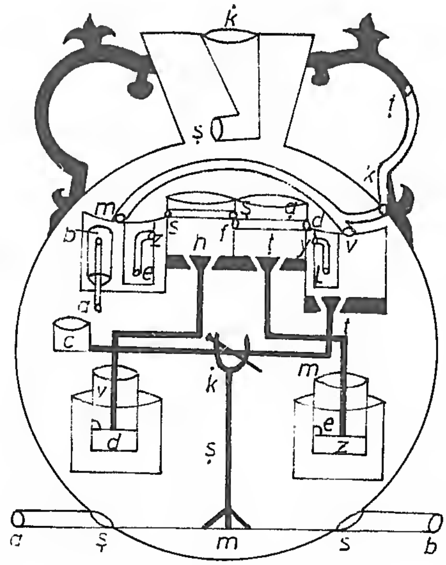


Figure 72–a (T)

Model 70-A Jar With a Free Outflow Which Filled by Water and Wine Pours out Continuosly the Liquid in Desired Successions (Figure 70-a)

The water which is poured slowly through the hole ķ into the jar flows from the funnel ķ-l into the tank a containing the closed valve ţ. The wine which is poured forcefully as the second through the hole ķ goes through the air obstacle h-c-d over the tank t into the tank z which is on the left arm of a balance with two positions (see Motif 6) that is mounted in the tank t. As long as the tank z is full or the filling of the wine into the jar continues the balance is inclined to the left side. The wine overflowing tank z collects in tank t and the air goes out through the pipe s-m. When the filling of the wine ends the tank z empties, the equilibrium of the balance changes, inclining to the right the valve y on the bottom of tank t opens. If the air entrance hole m is closed by hand, nothing flows out from the jar.

When the user opens the hole m, the wine in the tank t flows into the tank l containing a floated tank (see Motif 5). As long as the floated tank a is full, or wine flows from tank t and the hole m is open, the wine overflowing the tanks ạ and l pours out through the outflow k. If the user closes the hole m or the air entrance of the tank t, the outflow of the wine ceases; as the tank ạ discharges, with the raising of the float s, the valve ţ opens and the water of the tank a begins to pour out. When the hole m is opened again the outflowing wine fills up the tank ạ, the tank ş is pushed back and the valve ţ closes. Thus, as long as the tanks t and a contain liquids, the kind of the outpouring liquid can be changed by closing or opening the hole m.

The block diagram of the system is given in Figure 70-b. At the filling the liquids are directed to different tanks by flowrate control (see Motif 3). The outflowing liquid is determined by a floated tank (see Motif 5) working together with an air control motif (Motif 7). After filling, the system is triggered by a balance with two positions (see Motif 6).

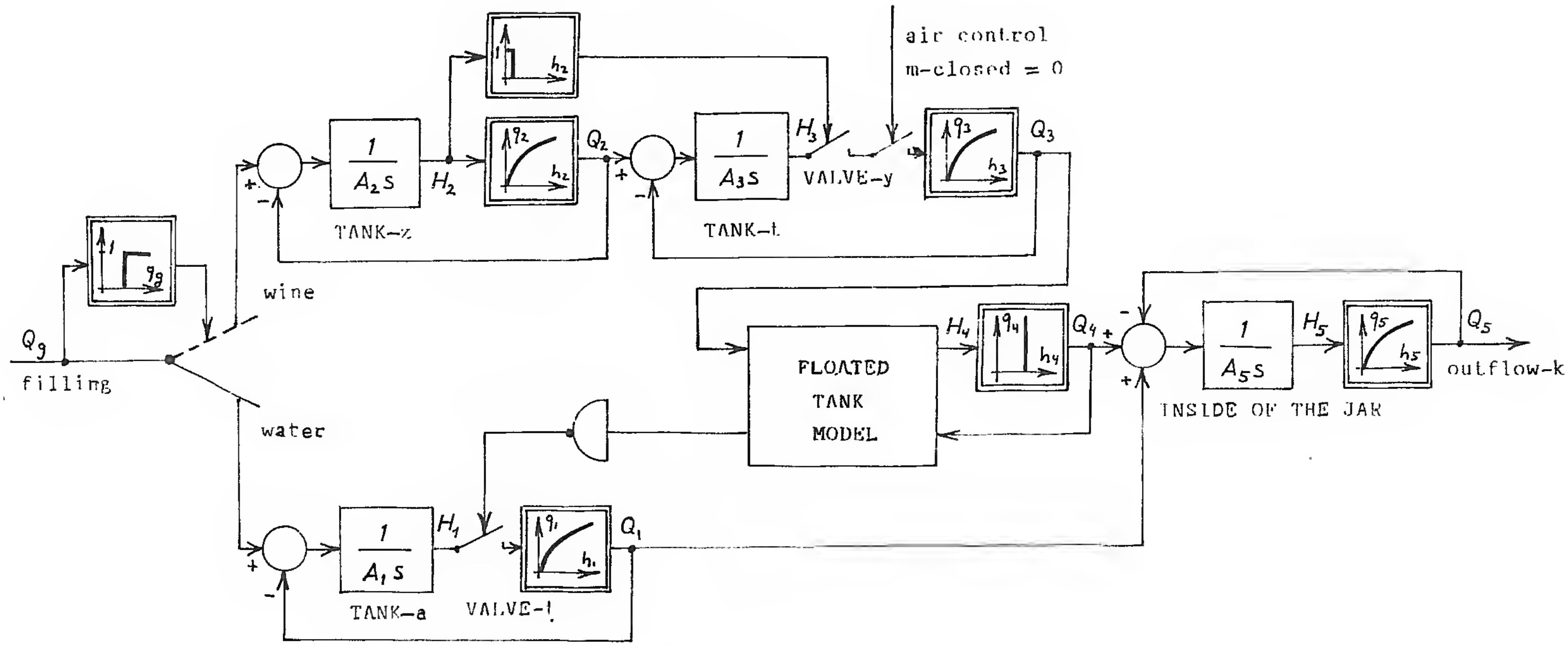

air control
m-closed = 0
Q3
Q2
H3
VALVE-y
TANK-t
TANK-z
H2
wine
Qg
filling
water
H4
Q4
Q5
H5
outflow-k
FLOATED
TANK
MODEL
INSIDE OF THE JAR
H1
Q1
TANK-a
VALVE-!

Figure 70-b

Model 71-A Jar With Two Free Outflows Which, After Being Filled With Wine and Water, Pours out As Required From the Outflows a Water-Wine Mixture or Nothing; From One Outflow Water From the Other Wine or Vice Versa (Figure 71-a)

First wine is poured forcefully into the jar through the hole **a**. The wine flows from the funnel **a-h** passing the air obstacle s-**h** in the tanks **l-h** and **c-e**. The filling of the wine continues as long as the siphons **l** and **c** in the tanks **l-h** and **c-e** start to pour out. Secondly, water is poured gently into the jar through the hole **a**. Similarly the water flows from the funnel **a-h** passing the air obstacle **ţ-z** in the tanks **a-v** and **k̇-n**. The filling of the wine ends when the siphons **a** and **k̇** begin to pour out. However it is not clear how the liquids are filled into the jar, since when the siphons **l** and **c** start to pour out, the flow of the wine can only be stopped by closing the air entrance, but then it is not possible to fill the tanks **a-v** and **k̇-n** with water. Perhaps when the wine begins to flow out, the outflows **k** and s are closed by hand and an equivalent quantity of wine is filled gently into the jar. After filling, when the holes **k** and **b** are kept closed the liquids do not flow out, when opened a water-wine mixture flows out from the outflows. If only the hole **k** is closed, water flows out from the outflow **k** and wine from the outflow **b**; and if only the hole **b** is closed wine flows out from the outflow **k** and water from the outflow s.

The block diagram of the system is given in Figure 71-b. The liquids are directed to different tanks during filling by the flowrate control (see Motif 3). The place of outflow for the liquids are determined by air control (see Motif 7).

Model 72-A Jar With Two Free Outflows Which, After Being Filled With Water and Wine; Pours out As Required From One Outflow Water From the Other Wine or Vice Versa (Figure 72-a)

First water is poured forcefully into the jar through the hole **k̇**. The water flows from the funnel **k̇-ş** (see Motif 3) into the tank **h**. Since at the beginning the valve **h** is closed the water level in tank **h** rises and

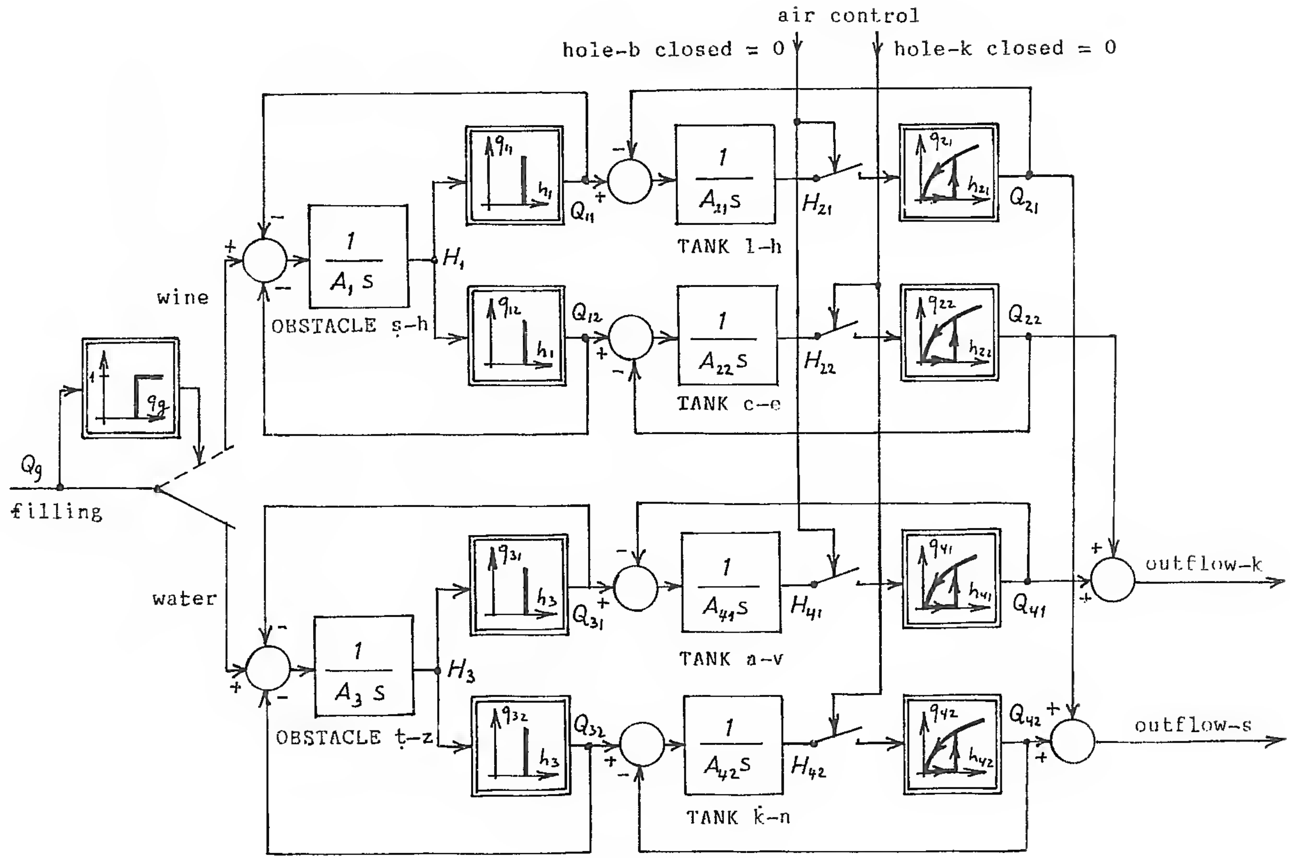
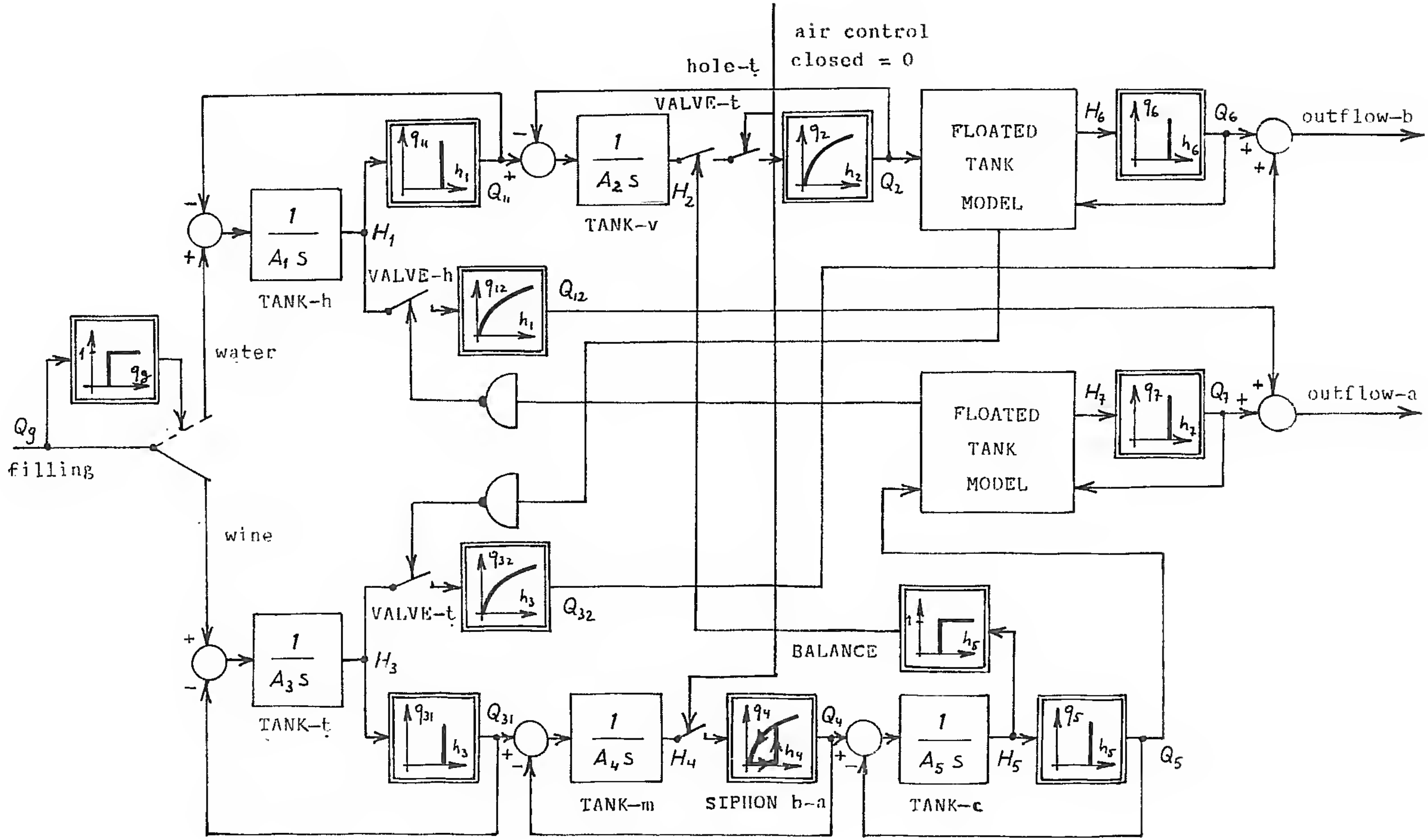

air control
hole-b closed = 0
hole-k closed = 0
filling
wine
water
OBSTACLE ṣ-h
OBSTACLE ṭ-z
TANK l-h
TANK c-e
TANK a-v
TANK k̇-n
outflow-k
outflow-s

Figure 71-b

when the level reaches f, the water overflows through the pipe f-d, goes through the air obstacle l-y and flows into the tank v. The valve t being also closed, the water collects in tank v and the air goes out following the way v-k-ţ. Secondly, wine is poured gently into the jar through the hole k̇. The wine flows from the funnel k̇-ş into the tank ţ with the closed valve ţ at the bottom. When the tank ţ is full the wine overflowing the pipe ş-s goes through the air obstacle e-z and flows into the tank m. The siphon b-a in the tank m begins to conduct when the level of the wine reaches b. The wine flows then into the tank c which is on the left arm of a balance with two positions (see Motif 6; in the original figure the extremity a of the siphon is drawn too far to the right, not over the tank c). With the flowing wine the equilibrium of the balance changes and the arm inclines to left, the valve t opens. The wine which overflows the tank c pours into a tank containing a floated tank and from there flows out through the pipe ş-a. At the same moment, with the opening of the valve t the water of the tank v begins to flow into another tank containing a floated tank and then pours out through the pipe s-b. The filling process ends when the wine begins to flow out from the outflow a and the water from the outflow b.

During the emptying process when the hole ţ is closed by hand the liquids cannot flow out from the tanks m and v, since the air entrance is blocked. Then the tank v on the float d empties, with the rising the valve h opens and the water of the tank h begins to flow out from the pipe ş-a. At the same time as the tank e on the float z also empties, the float z rises, the valve ţ opens and the wine of the tank ţ begins to flow out from the pipe s-b. Thus as long as the hole ţ is held closed water flows out from the outflow a and wine from the outflow b. If the hole ţ is opened the tanks v and e on the floats d and z fill again with liquids flowing from tanks m and v. With the decrease of the tanks d and z the valves h and ţ close and the system returns back to its first position. The outflow of the liquids from the outflows a and b in different forms continue as long as the tanks h, v, ţ and m contain liquids.

The block diagram of the system is seen in Figure 72-b. The separation of the liquids at the filling operation is realised by flowrate control (see Motif 3), the triggering of the outflow by a balance with two positions (see Motif 6), the control of the outflow place by two floated tanks



air control
closed = 0
hole-t
VALVE-t
TANK-v
FLOATED
TANK
MODEL
outflow-b
outflow-a
TANK-h
VALVE-h
water
filling
wine
VALVE-t
TANK-t
BALANCE
TANK-m
SIPHON b-a
TANK-c

Figure 72-b

(see Motif 5) and by air control (see Motif 7). This system is a double outflow version of Model 70, thus the number of the motifs are twice the ones used in Model 70.

Model 73-A Jar Which After Being Filled With Water and Wine Pours out the Required Liquid When the Tap is Turned on (Figure 73-a)

The hole s at the handle being closed with wax, first wine is forcefully poured into the jar through the hole **c**. The wine flows from the funnel **c-l** (see Motif 3) into the tank **v-e**, going through the air obstacle **ṭ-h-e**. When the level of the wine in the tank **v-e** reaches **v**, the siphon **v-z** transmits the wine to the tank **z-d** on the left arm of a balance with two positions. The filling of the wine is stopped, when the quantity of wine in tank **z-d** is sufficient to incline the balance to the left, but not enough to put siphon **d-m-y** into action. By inclining the balance to the left the valve **k** on the bottom of the tank **b-s** closes.

Secondly, water is poured gently into the jar through the hole **c**. The water flows from the funnel **c-l** into the tank **b-s**. When the filling process ends and the tap **k̇** is opened nothing flows out. If the wax which closes the hole s is taken away the wine continues to flow from the tank **v-e** into the tank **z-d** and when the level of the liquid in the siphon **d-m-y** reaches **m** the wine begins to flow out through the open tap **k̇**. If the air entrance hole s is closed again the tank **d-z** is emptied by the siphon **d-m-y** since the outflowing of the wine from the tank **v-e** is stopped. The equilibrium of the balance changes, inclining to the right, the valve **k** opens and the water of the tank **b-s** begins to flow out through the tap **k̇**. These operations can be repeated as long as the tanks **v-e** and **b-s** contain liquids. To stop the outflow of the liquids the hole s has to be closed as at the beginning just before the wine begins to flow out, when the tank **d-z** is half full and the valve **k** is still closed.

The block diagram of the system is given in Figure 73-b. The liquids are transmitted to different tanks during the filling by flowrate control (see Motif 3), the outflow is controlled by a two positional balance (see Motif 6) and the air control motif (see Motif 7). The siphon seen over the valve **k** is not necessary since the tank **b-s** is open. This kind of

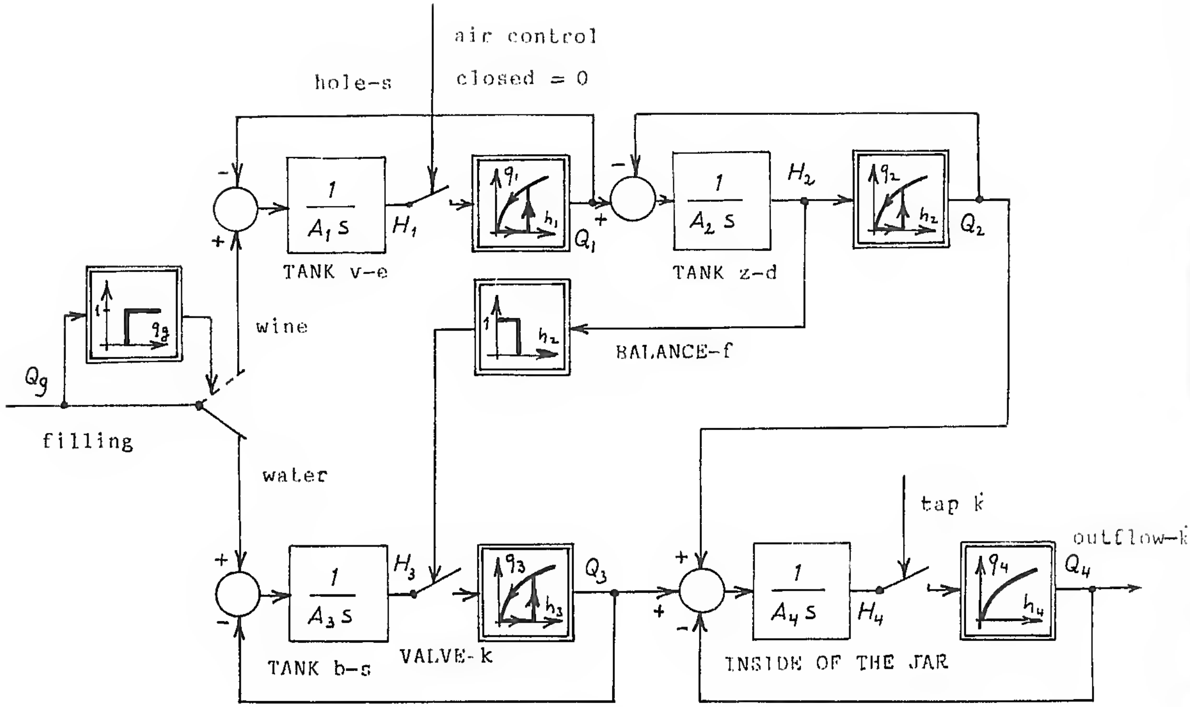


Figure 73-b

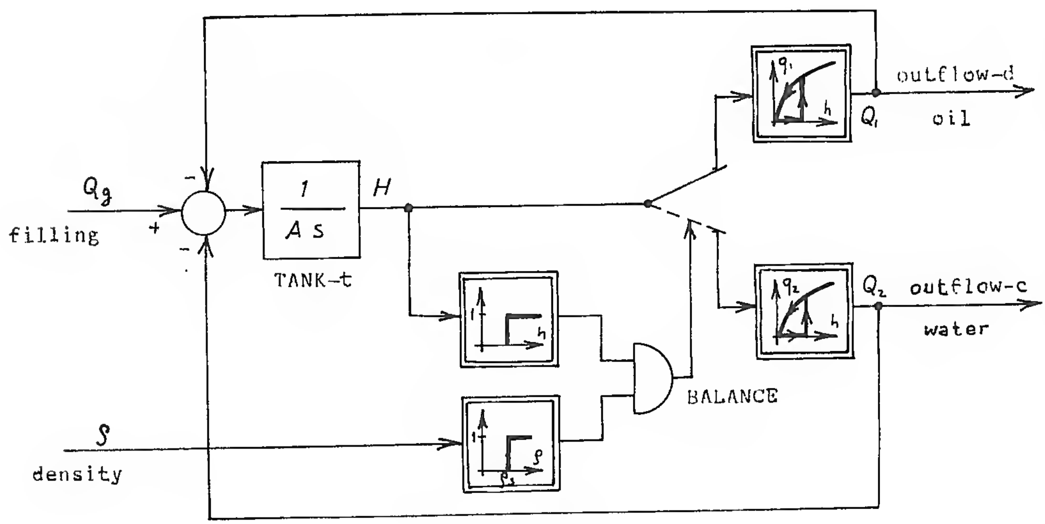


Figure 74-b

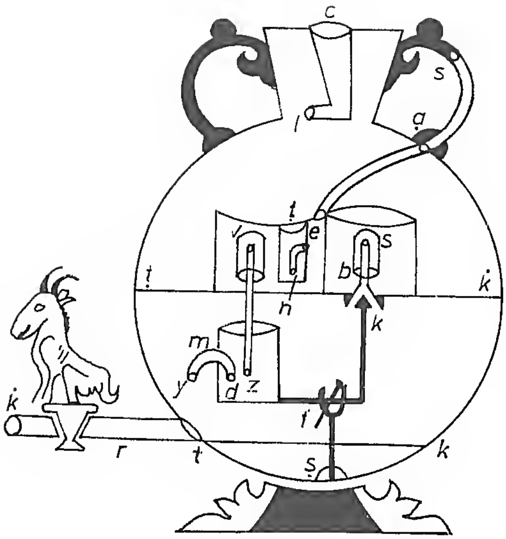


Figure 73—a (T)

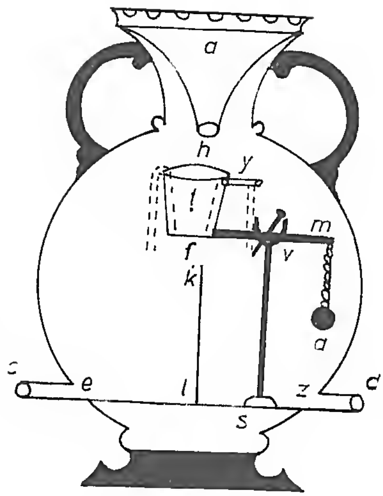


Figure 74—a (T)

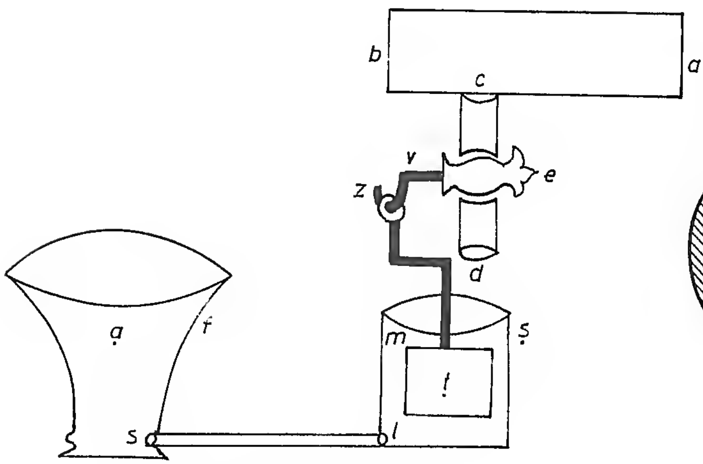


Figure 75—a (T)

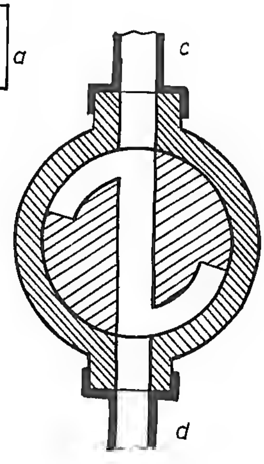


Figure 75-b

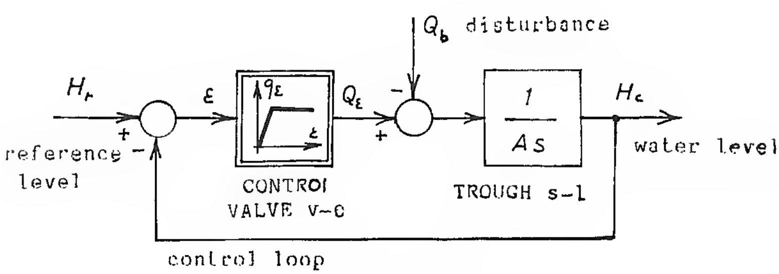


Figure 75—c

siphons have to be applied to tanks with air obstacles (as in Model 72), to prevent the air entrance through the valves or to prevent the outflow of the liquid during the filling of a tank (as in Model 59).

Model 74-A Jar Which Separates the Inpoured Water or Oil Outpouring Them Through Different Outlets (Figure 74-a)

Assume that oil is poured into the jar through the sieve-like plate **a**. The oil flows from the funnel **a-h** into the tank **ţ** on the left arm of a balance with two positions (see Motif 6). The equilibrium of the balance does not change when the tank **ţ** is full of oil. The oil overflows through the pipe y and goes out via outflow **d** (the pipe **y** has to be bent in the form of a siphon). When the filling process is interrupted for a short time the tank **ţ** is emptied by the siphon **y**. If water is filled into the jar through the lid **a**, the water being heavier that oil, the equilibrium of the balance changes just before the tank **ţ** becomes full and the arm inclines to the left. At this state, water begins to overflow through a siphon on the left side of the tank **ţ** (not shown in the figure) and begins to pour out from the outflow **c** of the jar.

The block diagram of the system is given in Figure 74-b. Here, the two positioned balance (see Motif 6) is used as a "densimeter", using the fact that the liquid with equal volumes but different densities have different weights. The volume of the tank **ţ** being **V**, the density and mass of the liquids ϱ_i and M_i, $(i=1,2)$, the ratio

$$V=\frac{M_1}{\varrho_1}=\frac{M_2}{\varrho_2}$$

is given. In the block diagram the density ϱ of the inpoured liquid is an input variable. In order to distinguish the liquids the equilibrium changing density ϱ_s has to realize the unequality

$$\varrho_1<\varrho_s<\varrho_2=\varrho_1\frac{M_2}{M_1}\ .$$

Model 75-A Trough Which Always Keeps a Constant Level Even When People Draw Water or Animals Drink From It (Figure 75-a)

The water of a basin or a river **a-b** is transmitted near to the trough ạ by the pipe **c-d**. At the end of the pipe **c-d**, there is a control valve **v-e** (see Motif 9). The cross section of the control valve reconstruction is seen in Figure 75-b. A crank shaft which is related to a float ţ by a ring is tied to the navel of the control valve **v-e**. As long as the trough ạ and the tank **m** connected by the pipe **s-l** are empty, the float ţ pulls the bar **z-v** down and keeps the control valve open (see the valve navel cross section in Figure 75-b). The water pouring out from the pipe **c-d** flows first into the tank **m** and then passing through the pipe **l-s** flows also into the trough ạ. The water obeying the law of connected tanks rises equally in the trough ạ and the tank **m** so that by the aid of the crank shaft, the float ţ begins to turn the navel of the control valve. When the level of the water reaches **m-ş** the navel of the control valve is turned off and the outpouring of the water ceases.

When people draw water or animals drink from the trough, by the decreasing of the water the float ţ comes down, the valve navel turns on and the same quantity of water as drawn out flows in the tank **m-ş** through the pipe **c-d**.

The block diagram of the system is given in Figure 75-c. In this automatic control system which is designed for practical purposes, the reference water level is given by the level **m-ş** which is determined by the length **m-z** of the bar connecting the crank shaft to the float ţ. In the diagram the actual water level is given by h_c. The valve **v-e** pours out water from the pipe **c-d** with the flowrate q_ε proportional to the level difference $\varepsilon = h_r - h_c$ (here the pipe pressure has been assumed constant). The drawn water from the trough (or the disturbance) is shown by q_b. The medium cross section of the trough ạ and the tank **m** together are taken as **A**.

Model 76-A Basin Which Stays Empty As Long As Wine is Being Filled in the Tank Behind it, When the Inpouring Ends the Basin Fills and Keeps a Constant Level Even When Wine is Drawn Up (Figure 76-a)

The wine is poured into the tank at the back of the basin, through the air obstacle **c-z-d**. The inpoured wine flows first from the pipe **d** into the tank **e-ḥ** which is on the left arm of a two positional balance (see

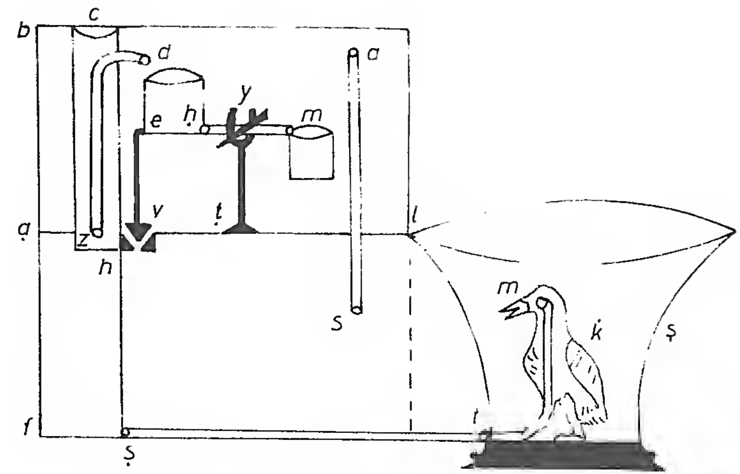


Figure 76–a (T)

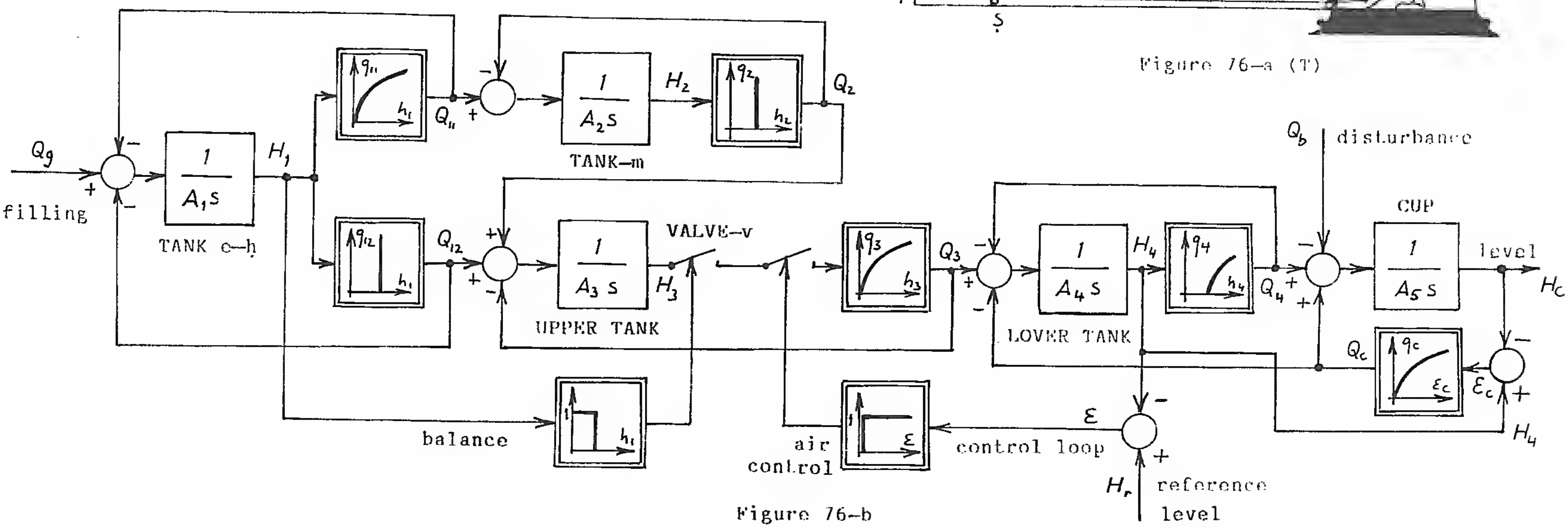


Figure 76–b

Motif 6), then passing the pipe **ḥ-m** which forms the arm of the balance, the wine flows into the tank **m** and overflowing the tank **m**, collects at last in the upper tank. As long as the filling continues, or the tank **e-ḥ** is full, the balance is inclined to the left and the valve **v** is closed. When the filling process ends the tank **e-ḥ** empties over the pipe **ḥ-m**, the equilibrium of the balance changes and by the inclining of the balance towards the right the valve **v** opens. When the wine in the upper tank flows through the valve **v** into the lower tank, the air of the lower tank passes to the upper tank through the pipe **s-a**. If the level of the wine on the lower tank reaches **m**, a part of the wine flows to the basin following the pipe **ṣ-t-m** (the pipe **t-m** is camouflaged in the body of a bird). The flow of the wine from the upper tank ceases when the level of the wine in the lower tank and the basin reaches s, because the air entrance to the upper tank through the pipe **s-a** is now prevented by the liquid blocking it. If wine is drawn up from the basin, the quantity of wine proportional to the level difference between the lower tank and the basin flow to the basin, and the wine in the lower tank is continuously supplied by the wine flowing from the pipe **s-a**, till the end s of the pipe is covered by the liquid.

The block diagram of the system is given in Figure 76-b. The filling process of the basin during the inpouring of the wine is prevented by a two positional balance (see Motif 6). The control loop is formed by the air control motif (see Motif 7). The reference level h_r is determined by the s end of the pipe **s-a**, and h_4 being the level of the basin, the difference $\varepsilon = h_r - h_4$ is intended to be annuled. The liquid flowing into the basin is proportional to the level difference $\varepsilon_c = h_4 - h_c$, here h_c is the level of the liquid in the basin. In the original text it is also pointed out that if oil is used in place of wine and an oil lamp is taken in place of a basin this model can be used for the control of the oil level.

Model 77-A Basin (or a Trough) Which Keeps a Constant Level When the Contained Wine is Drawn Up Sparringly and Empties When It is Drawn Up Abundantly (Figure 77-a)

The wine is filled into the tank at the back of the basin through the hole **ạ**. When the filling process of the upper tank ends, a quantity of wine is also poured into the basin from the outside. The basin and the tank containing a floated valve are connected by the pipe **e-b**. With the rising of the wine level in the connected tanks **e-b**, the float s also rises and the tied valve **l** opens (the valve **l-m**, whose reconstruction is given in Figure 77-b, has the property to be controlled in a level interval). The wine begins to flow from the upper tank into the tank **e-b**,. When the level of the wine reaches a reference level, determined by the intermediate arm length **l-m** of the valve, the valve **m** closes and the flow of the wine ceases. When wine is drawn up sparringly from the basin, if the fall of the level is less than the arm length **l-m** of the valve, the system restores the reference level by opening and closing the valve **m**. When the wine is drawn up abundantly and the fall of the level exceeds the arm length **l-m** of the valve, the valve **l** closes and the level of the basin cannot be controlled any more. To put the valve into action again, one has to pour a quantity of wine into the basin from the outside.

The block diagram of the system is given in Figure 77-c. In order to evaluate the half open position of the valve **l-m** the valve is modelled by a multiplication element. The control loop is formed in order to annul the level difference $\varepsilon = h_r - h_c$. The reference level h_r is determined by the length of the arm stretching out between the float and the valve **m**. The deviation difference $\varepsilon_2 - \varepsilon_1$ on the valve characteristics corresponds to the length **l-m** of the intermediate valve bar.

Model 78-A Basin (Trough or Vessel) Which Keeps a Constant Level by the Water Flowing From the Mouth of a Lion, Each Time When Water is Taken Up (Figure 78-a)

A lion stays on a console at the side of a basin **f**. Water is filled into the tank behind the lion through the hole **ṭ**. The filled water first flows in the upper tank and then passing the pipe **c-y** containing the valve **d**, goes through the body of the lion, and flows out from the lion's mouth **m** into the basin **f** on the front. The basin **f** is connected to the tank **ş** containing the float **ḥ** by the pipe **ş-l**. By the rising of the water in the basin **f** and tank **ş**, the float **ḥ** also rises. When the level of the water in the connected tanks **ş-l** reaches the level **f-ş**, the arm **ḥ-z** connected to the float turns the crank shaft **e-z-v** and closes the control valve **d**. One continues to fill the water till the upper tank is full. If water is taken up from the basin **f**, the level of the water in the tank

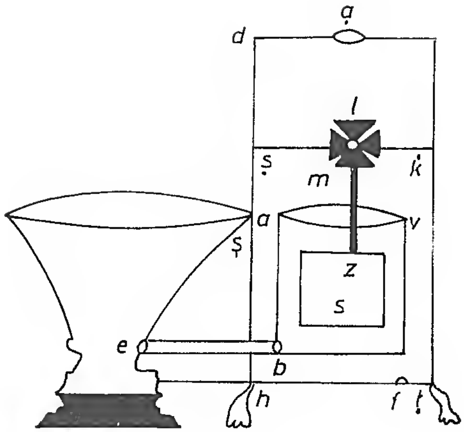


Figure 77—a (T)

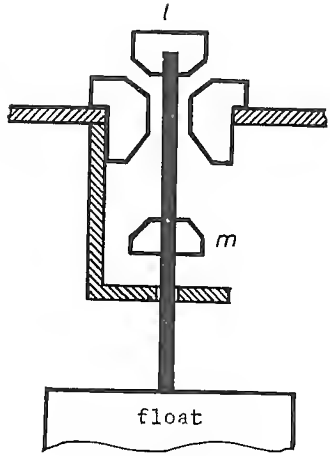


Figure 77—b

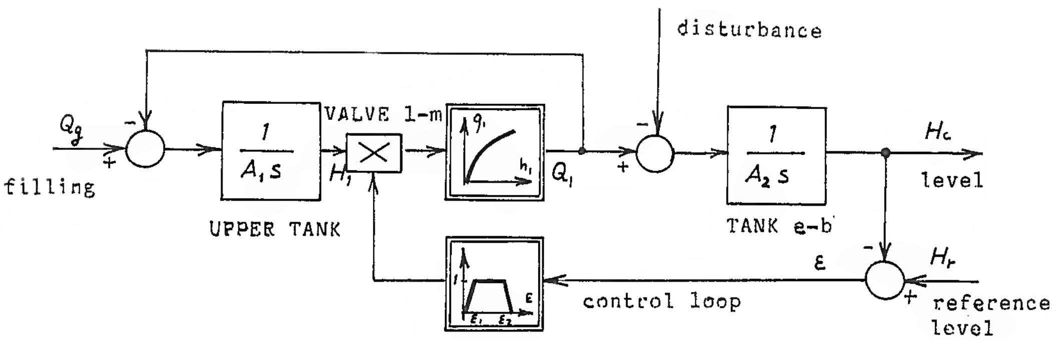


Figure 77—c

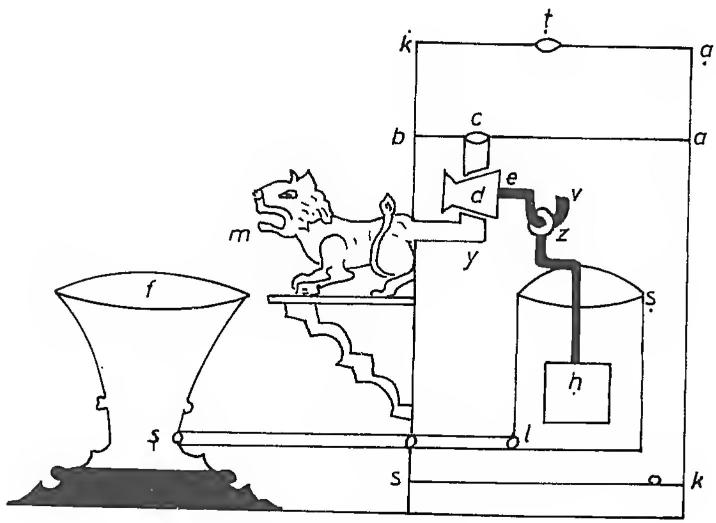


Figure 78—a (T)

ş decreases, the float ḩ descends and the valve d opens. After flowing from the mouth of the lion into the basin f, a quantity of water which is equal to the quantity drawn up, the level of the water reaches f-ş and the valve d recloses again. In this way the automatic control of the level continues so long as water exists in the upper tank.

The block diagram of the system is seen in Figure 78-b. The control valve d (see Motif 9) is shown by a multiplication element since the flowrate q_1 of the liquid is a function of the tank water level h_1 and the position of the valve navel. The control loop is formed in order to annule the level difference $\varepsilon = h_r - h_c$. The reference level h_r is determined by the length of the float arm ḩ-z. In the work it is pointed out that this system can also be used in baths and fountains.

Model 79-A Basin (Trough or Vessel) Which Keeps a Constant Level, by the Wine Flowing From the Mouth of an Ox, When the Wine is Taken Up Sparringly and Slowly; and Which Empties When the Wine is Taken Up Abundantly and Quickly (Figure 79-a)

A statue of an ox is standing in front of a basin ş. The tank behind the ox is filled by wine through the hole h. The valve e is closed when the basin z and the tank s are empty. When the filling process ends, some quantity of wine is also poured into the basin z. The wine flowing to the tank s following the pipe z-s, rises the float ẓ and the valve e opens. With the opening of the valve e the wine passing through the pipe f-ḩ, first begins to flow from the upper tank into the tank ḩ and when the tank ḩ fills, overflowing the siphon m-l the wine flowing through the statue pours out through the mouth of the ox into the basin ş (a reconstruction of the tank ḩ and the siphon m-l is given in Figure 79-b). The wine pouring in the basin ş flows into the tank s passing through the pipe z-s, so that with the rising of the wine level in the tank s the float ẓ also rises. The valve e closes when the wine level in basin s reach the level k-ş. When the wine is taken up sparringly and slowly from the basin ş, with the sinking of the float in tank s, the valve e opens and the wine flowing from the mouth of the ox refills the basin after some delay. The delay tank ḩ added in the control loop helps to blockade the control process. Since when the wine is taken up

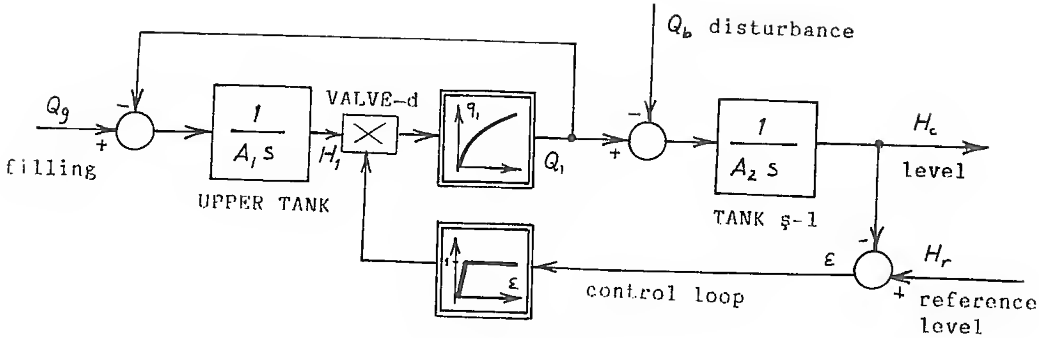


Figure 78-b

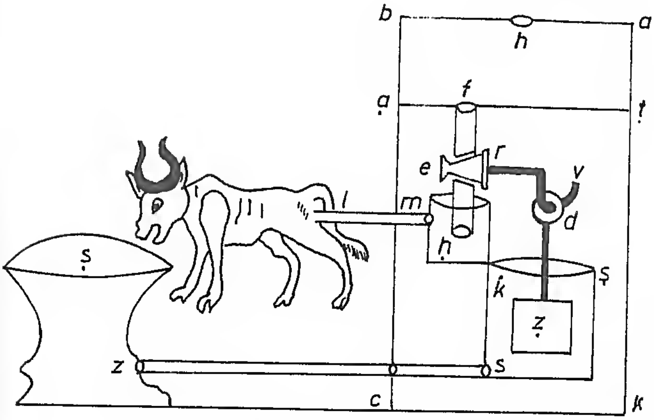


Figure 79-a (T)

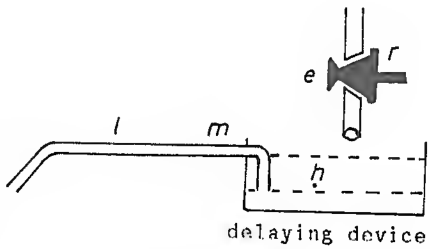


Figure 79-b

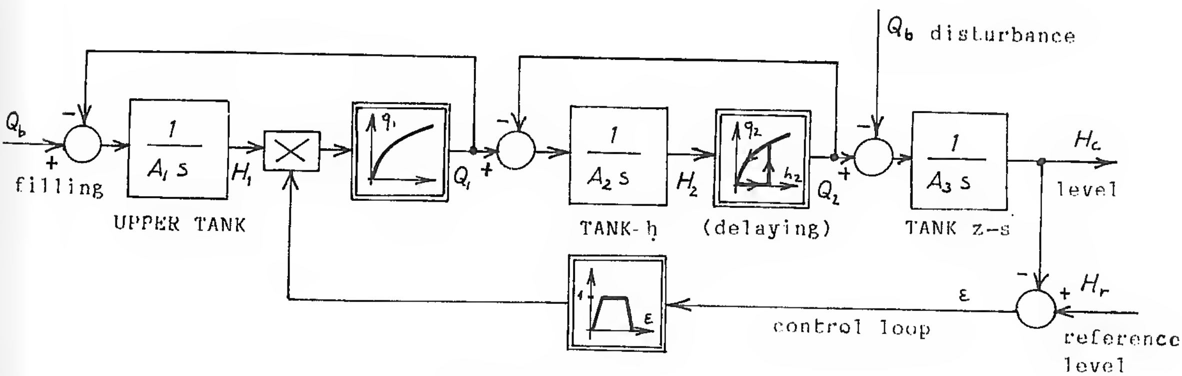


Figure 79-c

abundantly and quickly from the basin ş, the float ẓ turns up the valve e to the lower off position, so that the level of the wine level in the basin cannot be controlled any more. At this state to let the control system work again, a quantity of wine has to be poured in the basin ş and the valve brought to its working position. The wine level is controlled as long as liquid is available in the upper tank and wine is taken sparringly and slowly from the basin ş.

The block diagram of the system is given in Figure 79-c. This system is a combination of the models 77 and 78. Here, a control valve (see Motif 9) is used as a position transmitting control element. The valve characteristic depends on the form of the valve navel. The control loop tries to annul the level difference $\varepsilon = h_r - h_c$. The reference level h_r is similarly determined by the length of the float arm.

Model 80-A Basin (Vesel or Trough) Which Empties When Liquid is Taken Up Abundantly, and Keeps a Constant Level When Liquid is Taken Up Sparringly, by Mixed or Separately Inflowing Wine and Water (Figure 80-a)

First wine is inpoured forcefully through the hole **a** into the tank behind the basin. The poured wine flows from the funnel **a-d** into the tank **ṭ-k̇** (see Motif 3) The second gently inpoured water through the hole **a** flows in the tank **l-h**. At the beginning the valves **e** and **v** are closed. After the end of the filling process a quantity of wine is also poured into the basin **v**. A part of this wine flows through the pipe **ş-s** into the tank **f-ṭ** and raises the float **ạ**. The arm of the float **ạ** hangs on the hook **r-m** which is over the bar **r** connecting the navels of the valves **v** and **e**. The raising float **ạ** turns the bar **r** and opens the valves **v** and **e**. The wine of the tank **ṭ-k̇** flows over the pipe **ṭ-y-z** and the water of the tank **l-h** flows over the pipe **h-v-z** to the basin **v**. If the pipes on the end **z** are isolated then the liquids pour out separately and if they are united the liquids pour out mixed. The level of the wine-water mixture in the basin rises and when the level of the liquid reaches **v-f** the valves **v** and **e** are turned off by the float **ạ**.

If the wine-water mixture is taken up slowly and sparringly from the

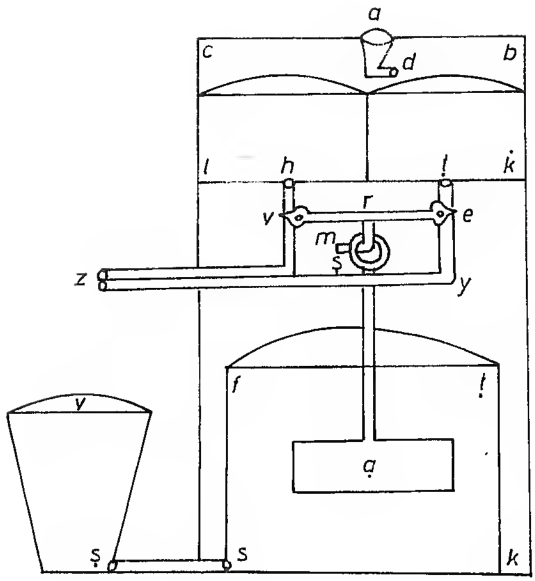


Figure 80-a (V)

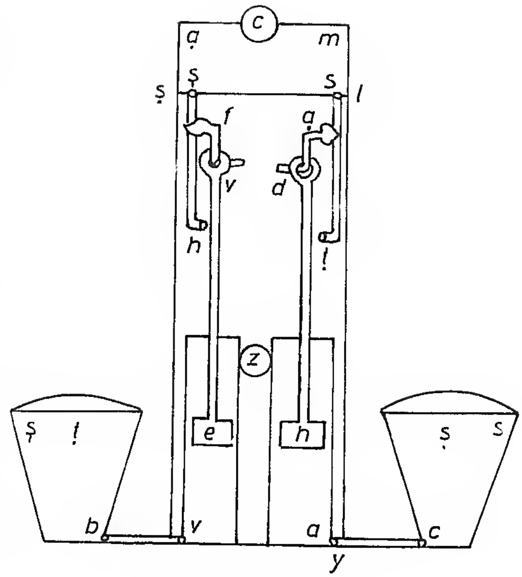


Figure 81-a (V)

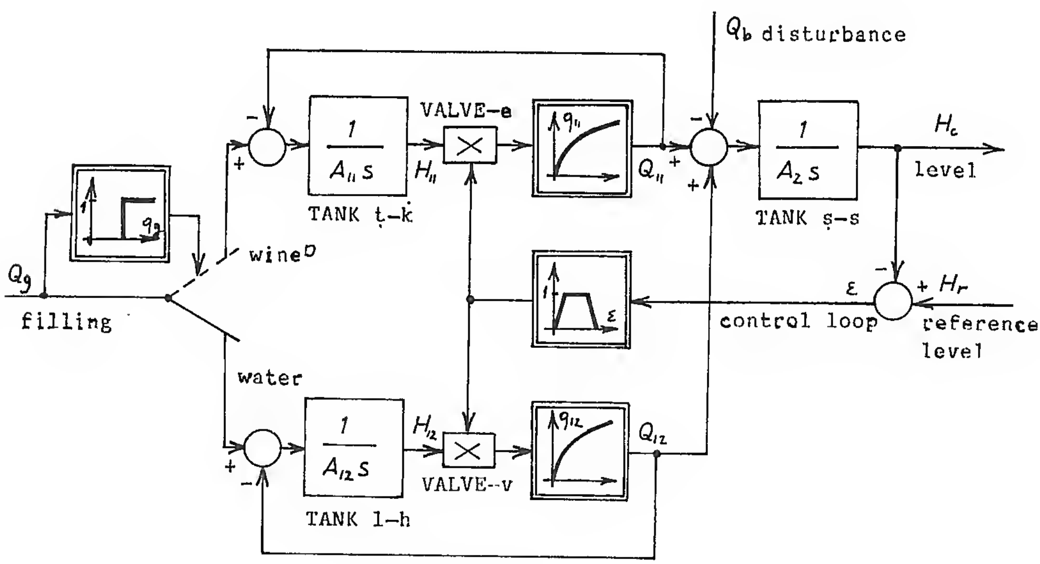


Figure 80-b

basin, with the decreasing of the float ạ in the tank **f-t** the valves **v** and **e** open and the basin is refilled by the liquid flowing from the tanks **ţ-k̇** and **l-h**. If the wine-water mixture is taken up quickly and abundantly from the basin **v** the float ạ turns the valves suddenly to the lower off position and the emptied liquid cannot be replaced any more. For the control system to work again a quantity of liquid has to be poured into the basin **v** from the outside and the valves brought to their working positions. Thus, the level control of the ḅasin **v** continues as long as water and wine exist in tanks **l-h** and **ţ-k̇**, and the mixture is taken sparringly.

The block diagram of the system is given in Figure 80-b. The working principle is similar to Model 79 but the refilling mechanism is dualised. In the work, it is stated that the kinds of the outpouring liquids change. The valve navels **v** and **e** should have on-off positions or holes corresponding to different levels. In order to define the sequence, one has to determine the quantity of the liquid taken up from the basin **v**.

Model 81-Two Basins Which Keep a Constant Level When Wine is Taken Up Sparringly Empty When Wine is Taken Up Abundantly; If it is Desired the Emptying Basin Can Be Brought to the "Level Keeping State" by the Basin Which Keeps the Level (Figure 81-a)

Wine is poured into the tank between the basins through the hole **c**. Since at the beginning the valves **f** and **ạ** are closed the wine gathers in the upper tank. After the end of the filling process a quantity of wine is also poured into the basins **ţ** and **ş**. Some part of the wine flowing through the pipes **b-v** and **c-a** into the tanks **v** and **a** raises the floats **e** and **h**, and opens the valves **f** and **ạ**. The wine passing the pipes **ş-h** and s-**ţ** flows into the basins **v** and **a**. The level of the wine in the basins **b-v** and **a-c** raises. When the level of the wine in the tank **ţ** reaches **ş-ţ** and in the tank **ş** to **ş-s**, the valves **f** and **ạ** close. If wine is taken up sparringly from the basins the lacking quantities are completed by the valves **f** and **ạ** controlled over the floats **e** and **h**. If wine is taken up abundantly and quickly, the large level difference takes the valve suddenly out of the control zone and the level of the basin cannot be further controlled. To bring the emptying basin again to the controlled state some quantity of wine has to be poured into the same basin or into the level keeping second basin. In the second case the poured wine flows through the hole **z** between the tanks **v** and **a** and brings the uncontrollable valve to the controlled zone. These procedures continue as long as wine exists in the upper tank.

The block diagram of this system containing two Models 75 is given in Figure 81-b. It is stated in the work that this model has been used in drinking parties to inebriate those not wishing to drink much. The conversant person empties his basin by taking wine abundantly, while the unknowing drinker is incapable of emptying his basin. If he tries to empty his basin of drink, and is doing so succeeds, the conversant drinker brings the valve of the basin into the controlled zone by laying his goblet in the basin, causing the wine to overflow into the other basin through the hole **z**.

Model 82-A Construction With Two Basins, When a Determined Quantity of Wine is Poured into One of the Basins, the same Quantity of Wine Fills Automatically into the second Basin; Now the Second Basin Keeps a Constant Level Even When Wine is Taken Up Abundantly (Figure 82-a)

Wine is poured into the tank between the two basins through the hole **y**. Since, at the beginning, the valves **ş** and **h** are closed, the inpoured wine gathers in the upper tank. After the end of the filling process a quantity of wine is poured into one of the basins (for example into the right side basin **a**, just enough to fill the tanks **a-c** and e). The poured wine flows through the pipe **a-c** into the tank **c** and raises the float **m** (in the original figure the floats **m** and **f** in the tanks **c** and **d** are not drawn). With the rising of the float **m** the valve **z** over the float closes. The wine poured into the basin **a**, after filling the tanks **a** and **c**, overflow through the pipe **m-e** into the tank **e** which is over the right arm of a three positioned balance (in the figure the position of the pipe **m-e** is not clear; the pipe **m-e** is tied on the tank **c** over the tank **e**, so that the movement of the balance is not handicapped). The three positioned balance (see Motif 8) which is on its middle position when the tanks are empty, lies to the right when the tank e fills. At the same moment the bars connected to the balance arms turning the crank shafts closes

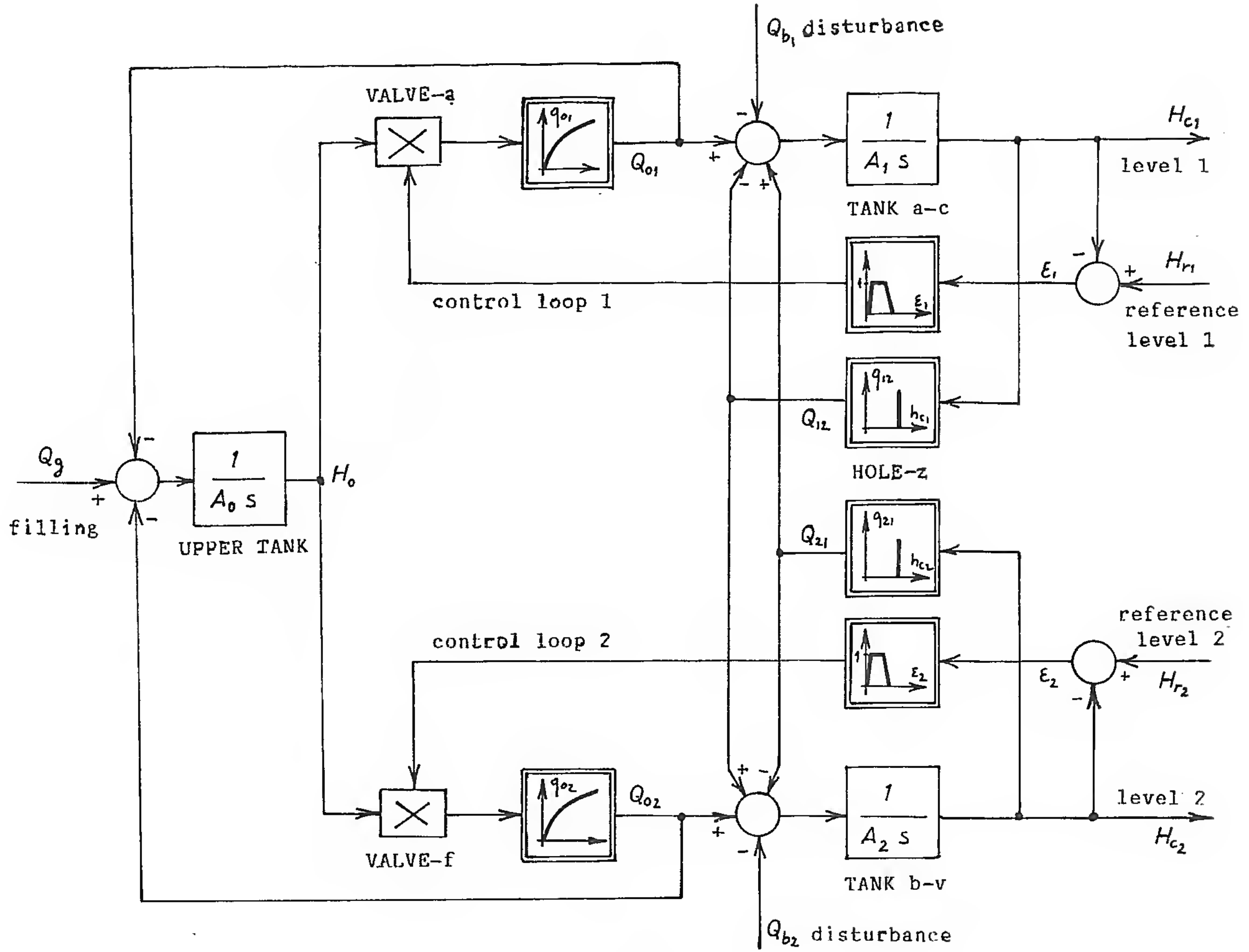

Qb1 disturbance
VALVE-a
Q01
Hc1
level 1
TANK a-c
Hr1
reference
level 1
control loop 1
Q12
HOLE-z
Qg
filling
Ho
UPPER TANK
Q21
reference
level 2
Hr2
control loop 2
Q02
level 2
Hc2
VALVE-f
TANK b-v
Qb2 disturbance

Figure 81-b

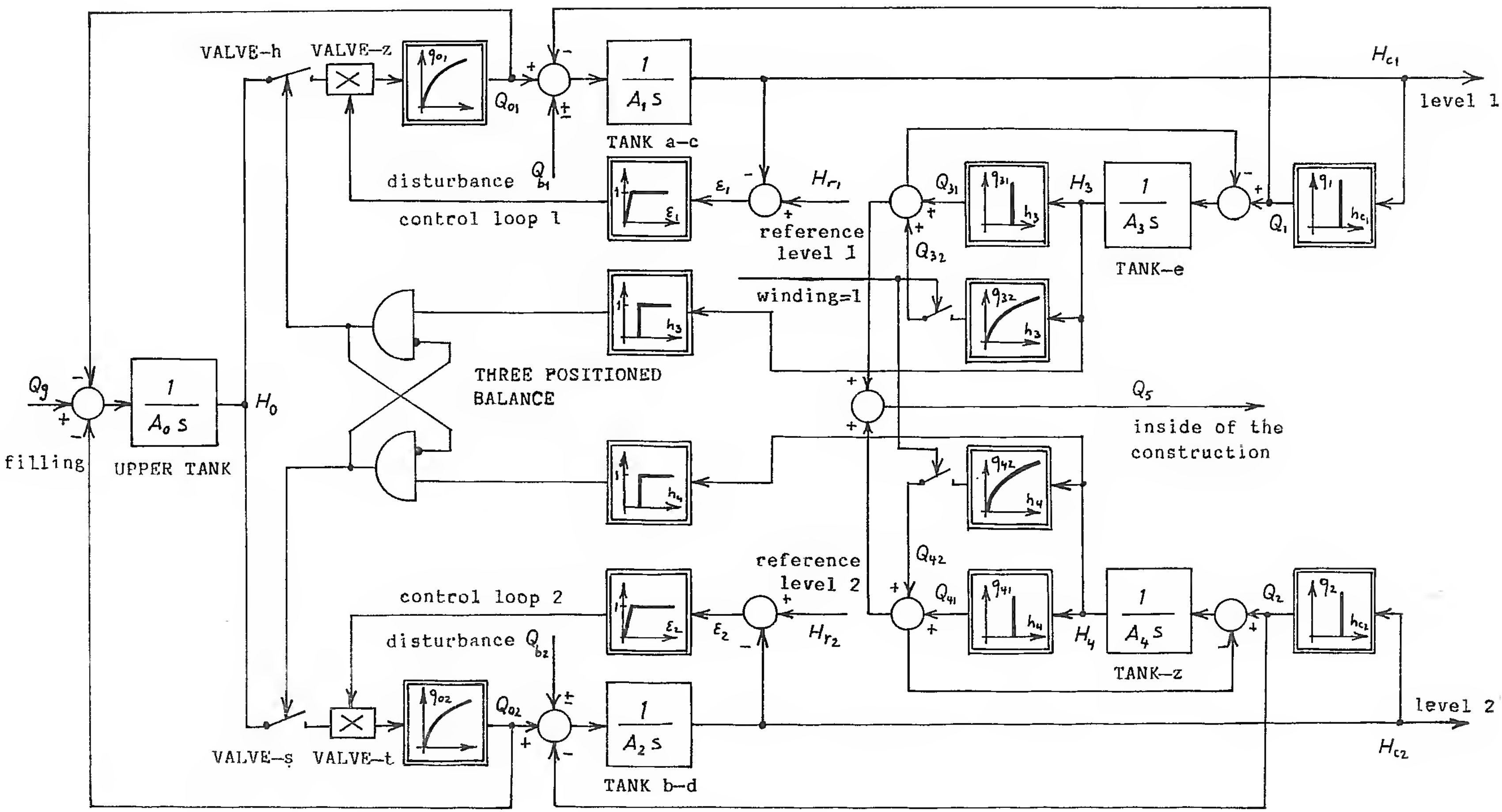
the tap **h** and opens the tap **ş**. With the opening of the tap **ş** the wine of the upper tank flows through the pipe **s-t** into the tank **d** and over the pipe **d-b** into the basin **b**. Before the level of the wine in the tanks **b-d** reaches **f** the valve **t** in the tank **d** over the float **f** closes and the outpouring of the wine ceases.

When wine is taken up from the basin **b**, thereby decreasing the level, the valve **t** over the float **f** opens and the wine in the tanks **b-d** is again raised up to the same level. Meanwhile if wine is taken up from the basin **a**, although the float **m** opens the valve **z**, the tap **h** being closed the wine is not refilled. Thus the level of the basin **b** is continuously controlled as long as the upper tank contains wine. The model being symmetric, the same is also valid for the predetermined quantity of wine poured into the basin **b** at the beginning. This time the level of the basin **a** being preserved the wine taken up from the basin **b** is not supplied.

The block diagram of the system is seen in Figure 82-b. The action producing element the three positional balance one time brought out from the middle equilibrium state always remains in the same position. This locking property is characterised by a logic circuit in the block diagram. To return to it's original state, or to rewind the system, one has to discharge the tank **e** or **z**. In the work it is stated that this model is used at drinking parties, like the previous ones.

Model 83-A Basin (or a Trough) in Which the Level of the Liquid Returns to the Beginning Height After All Containing Liquid Has Been Taken Up (Figure 83-a)

Water or wine is poured into the tank behind the basin through the hole **f**. The inpoured liquid flows into the upper tank and through the pipe s-**ş** from the mouth of a deer in the basin **e**. The liquid rises in the basin **e** up to the level **c** and flows over the siphon **d-c-a** into the tank **a** (the reconstruction of the basin **e** and the tank **a** is given Figure 83-b). In tank **a** the level of the liquid and the float **b** rises closing the valve **l**. The levels of the liquids in basin **e** and tank **a** are at the same level. If liquid is taken up from the basin **e**, because of the siphon **d-c-a**, the level of the tank **a** continuously keeps the level of the basin **e**. If liquid is taken up abundantly and suddenly the siphon **a-c-d** empties



VALVE-h
VALVE-z
Q_{01}
$\frac{1}{A_1 s}$
TANK a-c
H_{c1}
level 1
disturbance Q_{b1}
control loop 1
ε_1
H_{r1}
reference level 1
Q_{31}
H_3
$\frac{1}{A_3 s}$
TANK-e
Q_1
Q_{32}
winding=1
THREE POSITIONED BALANCE
Q_g
filling
$\frac{1}{A_0 s}$
UPPER TANK
H_0
Q_5
inside of the construction
reference level 2
Q_{42}
Q_{41}
H_4
$\frac{1}{A_4 s}$
TANK-z
Q_2
control loop 2
disturbance Q_{b2}
ε_2
H_{r2}
level 2
H_{c2}
VALVE-s
VALVE-t
Q_{02}
$\frac{1}{A_2 s}$
TANK b-d

Figure 82-b

the tank **a** and the decreasing float **b** opens the valve **l**. But, since air enters into the siphon **a-c-d** during emptying, to control the level of the liquid, the basin **e** has to be first filled up to level **c** as at the beginning. With the entering of the liquid into the tank **a** the float **b** rises and the valve **l** closes again.

The block diagram of the system is given in Figure 83-c. The model is used in ritual ablutions, in baths or in "drink serving automats" as mechanisms offering predetermined quantities of liquids. The basin **e** and tank **a** which are connected by a siphon effect the control loop by hysteresis according to the level difference $\varepsilon = h_r - h_c$ (see Model 78). In order to achieve a perfect working condition the liquid has to be taken up suddenly and the level of the basin **e** comes to the open position. Otherwise the system begins to oscillate around this level.

Model 84-Another Basin (see Model 83) in Which the Level of the Water Returns Back to the Original Height After All Liquid Has Been Taken Up (Figure 84-a)

This model is a valveless (hydraulic) realisation of the previous model 83. The system is formed by a human statue standing on a bracket in front of a basin. The water is poured in through the hole **a**. Water flows into the upper tank passing the air obstacle **a-z-c**. When the level of the water in the upper tank reaches the end **f** of the siphon **ạ-f** the water begins to flow into the basin **m** over the pipe **f-k**, through the back and mouth of the statue. If the level of the water in the basin reaches the upper level of the siphon **m-d** the level of the water in the closed tank **d** in the construction also rises. Here when the level reaches the lower end of the pipe **ţ-h** the air entrance of the upper tank closes and the outflow of the water from the mouth of the human statue ceases (the pipe **s-l** is used for the air connection of the tank **d** with the outside; on the figure the end of the pipe is drawn prolonged into the tank). If water is taken up from the basin the water level of the tank **d** also decreases because of the siphon **d-m**. When the level of the water falls under the **ţ** end of the pipe **ţ-h**, the air enters into the upper tank following the way **s-l-ţ-h** and water begins to flow again from the mouth of the statue. Meanwhile the siphon **d-m** sucks the water of the tank **d** in the tank **m** so that at the end air enters into the siphon.

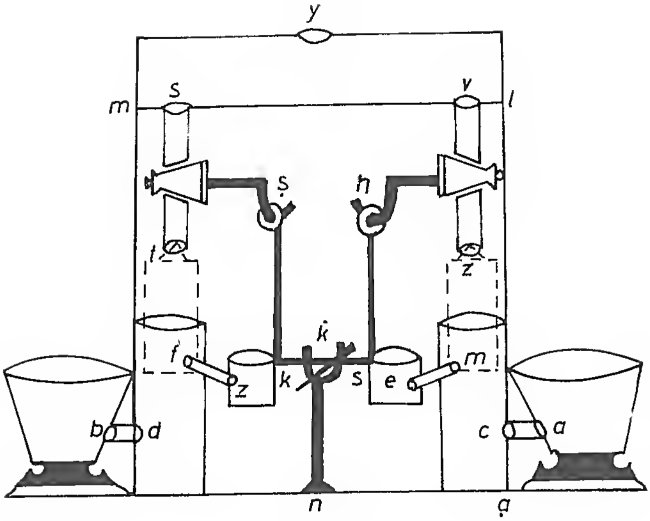
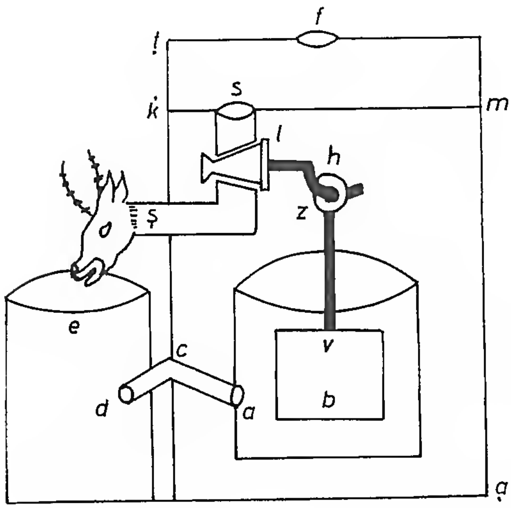


Figure 82–a (T)



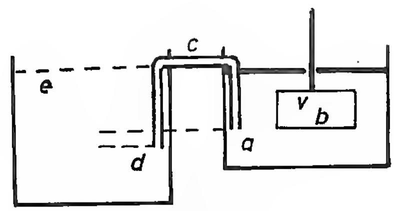


Figure 83–b

Figure 83–a (T)

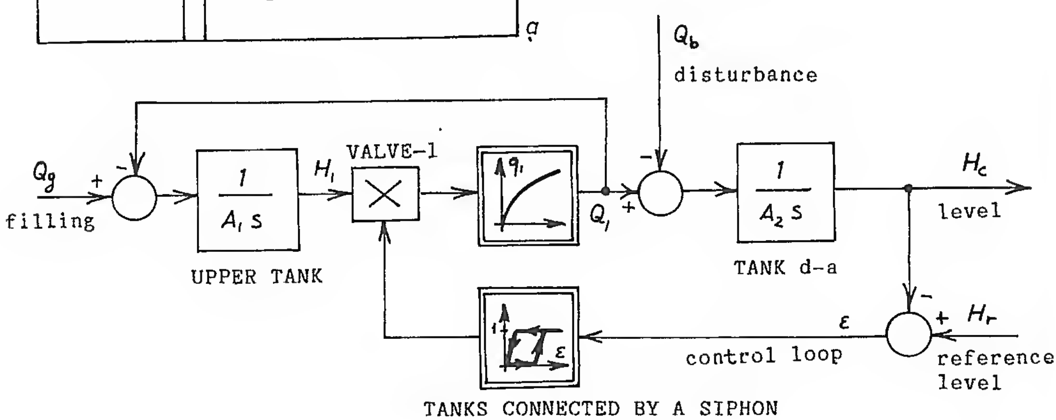


Figure 83–c

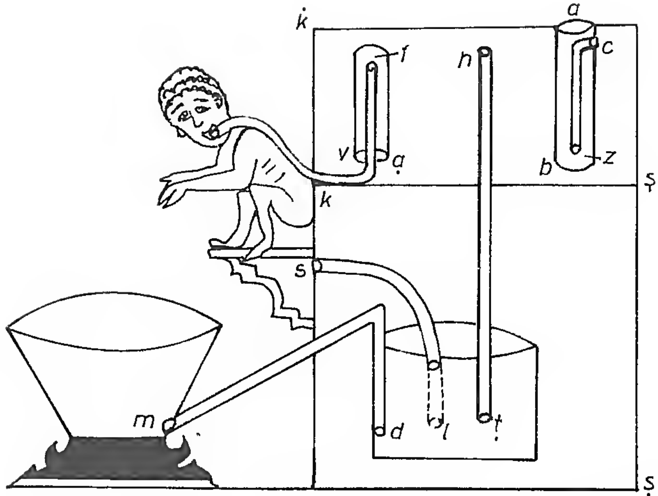


Figure 84-a (T)

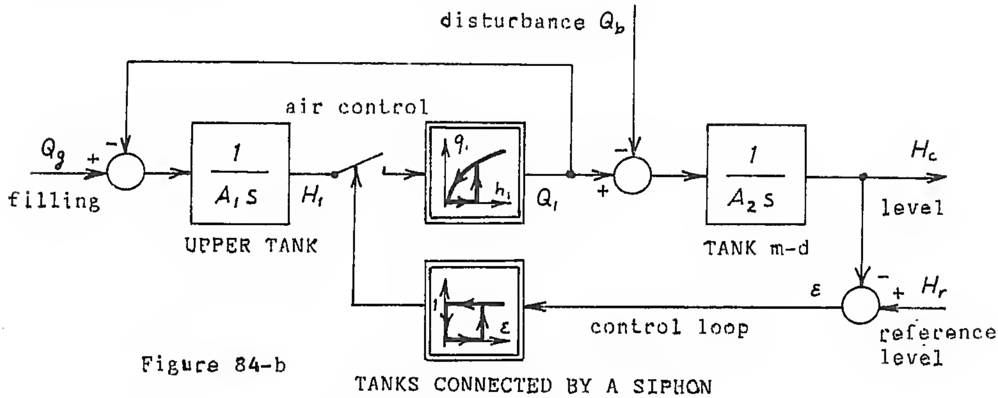


Figure 84-b

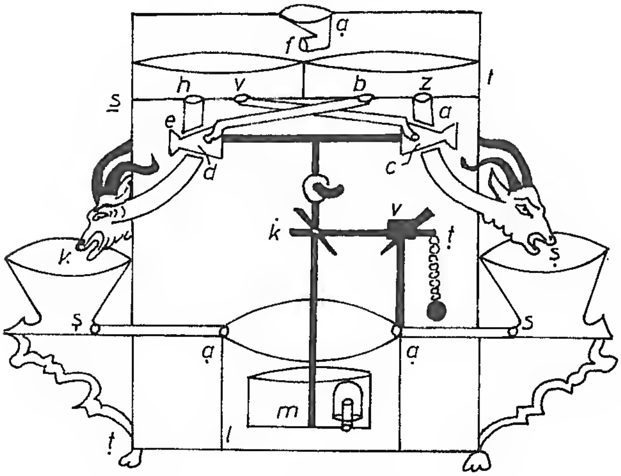


Figure 85-a (T)

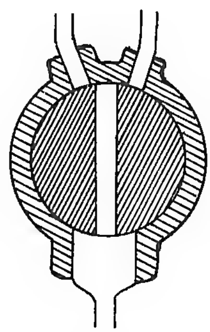


Figure 85-b

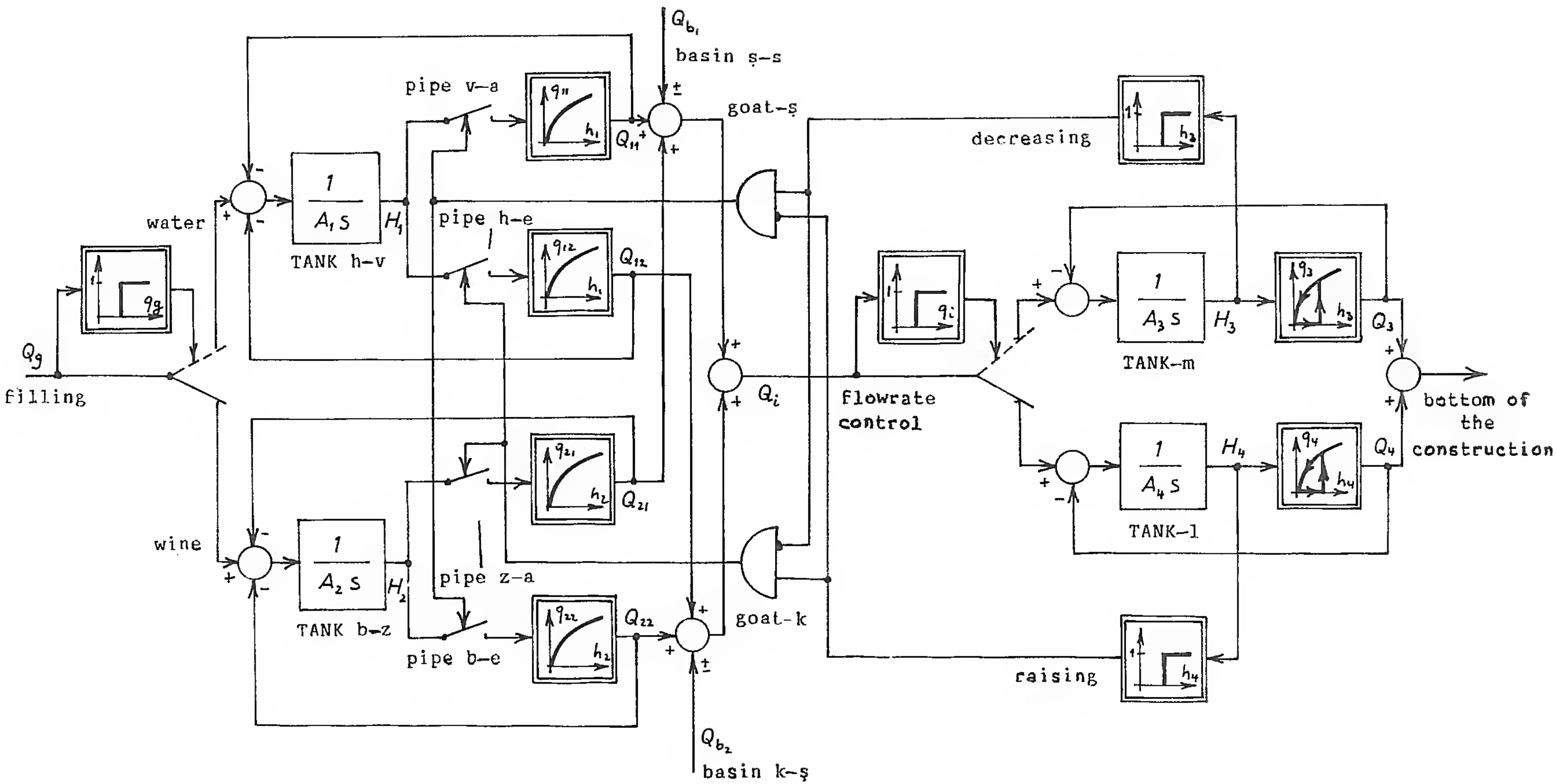
Otherwise, since the water pouring out from the mouth of the statue fills the basin **d**, the expected effect cannot happen. When water is taken up from the basin, for a perfect working, the level must fall under the critical level difference **ţ-d** (the end **m** of the siphon is lower than the end **d**).

The block diagram of the system is seen in Figure 84-b. In this model the air control motif is used as a control element (see Motif 7). The hysteresis effect occurs in the tanks connected through a siphon. The reference level h_r is determined by the **ţ** end of the **ţ-h** pipe. The control loop tries to annul the level difference $\varepsilon = h_r - h_c$.

Model 85-When Wine is Poured Slowly (Forcefully) in One of the Two Basins in Front of the Two Goats, Wine Pours out From the Corresponding Goat and Water From the Other; and if Water is Poured Forcefully (Slowly), Water Pours out From the Corresponding Goat and Wine From the Other (Figure 85-a)

First water is filled forcefully into the construction through the hole **ạ**. Water flows from the funnel **ạ-f** into the tank **h-v**. Secondly, wine is filled slowly through the hole **ạ** and collects in the tank **b-z**. Since the valves are closed at the beginning the liquids do not flow out. The navel of the valves **e-d** and **a-c** are bored, so that the outflow pipes are connected, according to the position, to the upper tanks or not (see Figure 85-b). On the crochet **k̇** which is over the valve navels connecting mile hangs the bar **k̇-m** with the tank **m** on its end. To close the valves, or to bring the navel to the middle position, the weight of the empty tank **m** is balanced by the three positioned balance **k̇-v-ţ** (see Motif 8).

If water is poured slowly into the basin **k-ş** which is on the front of the left side goat, the water flowing slowly into the tank **l** through the pipe **ş-ạ** raises the tank **m** and the bar **k̇** turns the valves upward. Then the water of the tank **h-v** flows over the pipe **h-k** and the mouth of the goat **k** into the basin **k-ş** the wine of the tank **b-z** flows over the pipe **z-ş** and the mouth of the goat **ş** into the basin **ş-s**. If wine is poured forcefully into the basin **k-ş** the wine passing forcefully the pipe **ş-ạ** flows into the tank **m** which is in the tank **l**. With this charge the tank



Q_{b_1}
basin ş-s
goat-ş
pipe v-a
Q_{11}
water
filling
Q_g
q_g
TANK h-v
H_1
pipe h-e
Q_{12}
decreasing
Q_i
flowrate control
TANK-m
H_3
Q_3
bottom of the construction
TANK-1
H_4
Q_4
wine
TANK b-z
H_2
pipe z-a
Q_{21}
pipe b-e
Q_{22}
goat-k
raising
Q_{b_2}
basin k-ş

Figure 85-c

m decreases and the valves turn downward. At this position wine flows out following the way **b-d-k** through the mouth of the goat **k** and water flows out following the way **v-c-ş** through the mouth of the goat **ş**.

This procedure is also valid for slowly poured wine and forcefully poured water into the basin **ş-s**. To bring the system to its first state, a siphon is set into the tank **m**. To empty the used liquids and to bring the model to it's original state another siphon has to be put into the tank **l** (not shown in the figure).

The block diagram of the system is shown in Figure 85-c. The system action depends on slowly and forcefully pouring liquids into the basins. This model is apparently designed to show the application of the valve with the special navel, seen in Figure 85-b.

Model 86-A Basin (or Trough) With a Beast Above it Which Begins to Discharge When Wine is Poured in and Ceases Discharging When Pouring is Stopped (Figure 86-a)

The wine which is poured through the hole **t** into the construction behind the beast, passing the air obstacle **t-h-d**, collects in the upper tank. When the level of the wine in the upper tank reaches the end **m** of the siphon, the wine begins to flow into the partition **k** which contains two siphons. The wine flowing over these siphons into the tank **ş-c**, passing through the pipe **c-ţ** and the mouth of the beast pours out in the basin **ạ**. The basin **ạ** and the tank **ş** are connected by the pipe **ạ-ş**. When in the basin **ạ** the wine covers the end **ạ** of the pipe **ạ-ş**, the air entrance in the construction being prevented, the outflow of the wine ceases.

If, a quantity of wine is poured from the outside into the basin **ạ**, the air pressure which is generated in the construction by this extra wine is equilibrated by the outflowing wine through the siphons. The procedure continues till the level of the wine in the construction reaches to the upper end of the basin **ạ**.

The block diagram of the system is given in Figure 86-b. The behavior of the system depends on the pressure equilibrium in the construction. If the level of the tank **ş** is designed by h_i, and the level of the basin

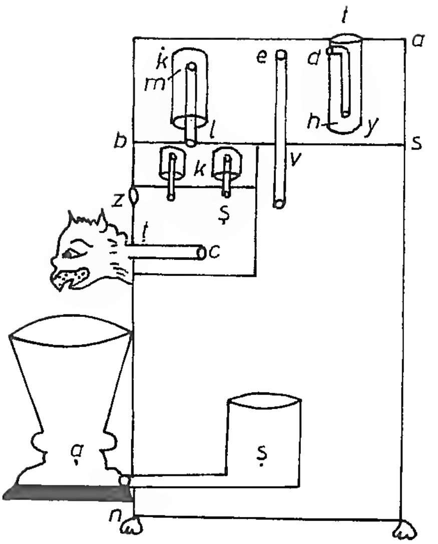


Figure 86–a (T)

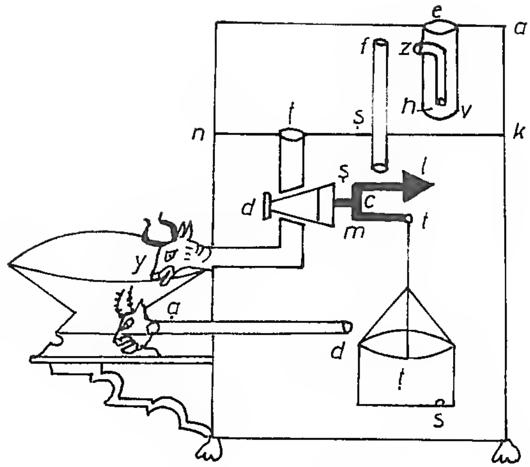


Figure 87–a (T)

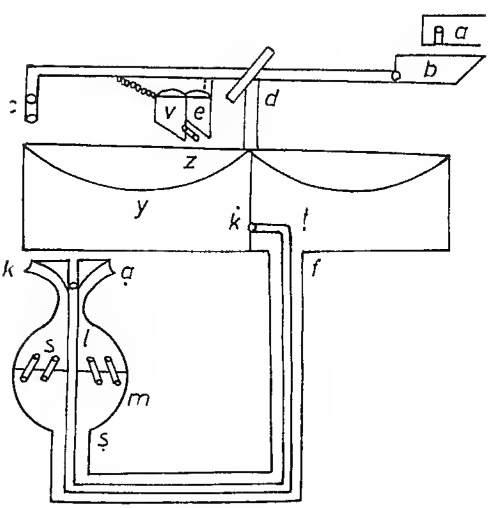


Figure 89–a (V)

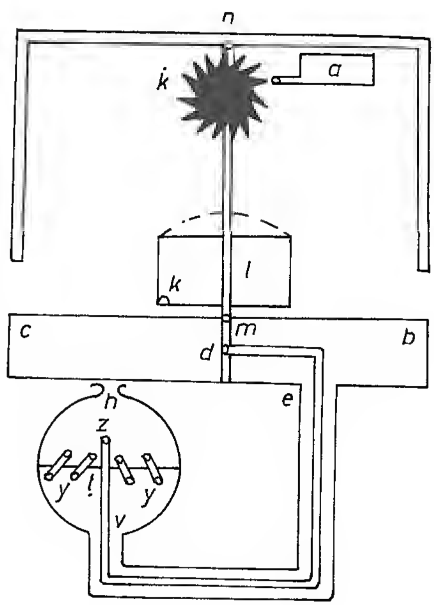


Figure 90–a (V)

ạ by $\mathbf{h_d}$, the level difference $\Delta\mathbf{h} = \mathbf{h_d}\text{-}\mathbf{h_i}$ generates the pressure difference $\Delta\mathbf{p}$. The pressure difference $\Delta\mathbf{p}$ effects a quantity of wine to flow from the basin **ạ** into the tank **ş** and another quantity of wine pours out from the upper tank into the basin **ạ**. In the block diagram it is assumed that a first order lag, having the time constant τ, exists between the level difference $\Delta\mathbf{h}$ and pressure difference $\Delta\mathbf{p}$. The given block diagram is a simple linear model intending to explain the principle. A sophisticated model evaluating all the effects can also be given.

Model 87-Another Vessel (see Model 86) **With Two Antelopes Which Begins to Discharge When Water is Poured in and Ceases Discharging When the Pouring is Stopped** (Figure 87-a)

The water is poured through the hole **e** in the construction behind the two antelopes, one drinking from the vessel and the other leaning forward. The water collects in the upper tank passing the air obstacle **e-h-z**. The valve **d** is closed at the beginning. The air goes out from the upper tank passing the pipes **f-ş** and **d-ạ**. After the end of the filling process a predetermined quantity of water is forcefully poured in the vessel. The inpoured water flows through the mouth of the drinking antelope and the pipe **ạ-d** into the tank **ţ**. The tank **ţ** hangs on the arm **m-ş** fixed to the valve navel **d** and is balanced by the counter weight **l**. When the tank **ţ** fills up by water, the equilibrium of the system which formes a two positional balance on the valve navel changes position and the valve **d** turns open. The valve stays open as long as the tank **ţ** contains water. Since the flowrate of the water, flowing through the pipe **ţ-y** and the mouth of the antelope **y** into the vessel when the valve **d** is open, is not enough to spout the water from the pipe **ạ-d** into the tank **ţ**, the fullness of the tank **ţ** is determined only by the water poured into the vessel from the outside. When the pouring of the water is stopped from the outside, the tank **ţ** empties over the hole s and the valve **d** returns to the closed position. This operation can be repeated as long as water exists in the upper tank.

The block diagram of the system is given in Figure 87-b. Here the two positional balance motif is combined with a two positional valve motif (see Motif 9). This model forms an open loop control system since the quantity of the water outflowing from the upper tank is determined by the liquid poured into the vessel from the outside.

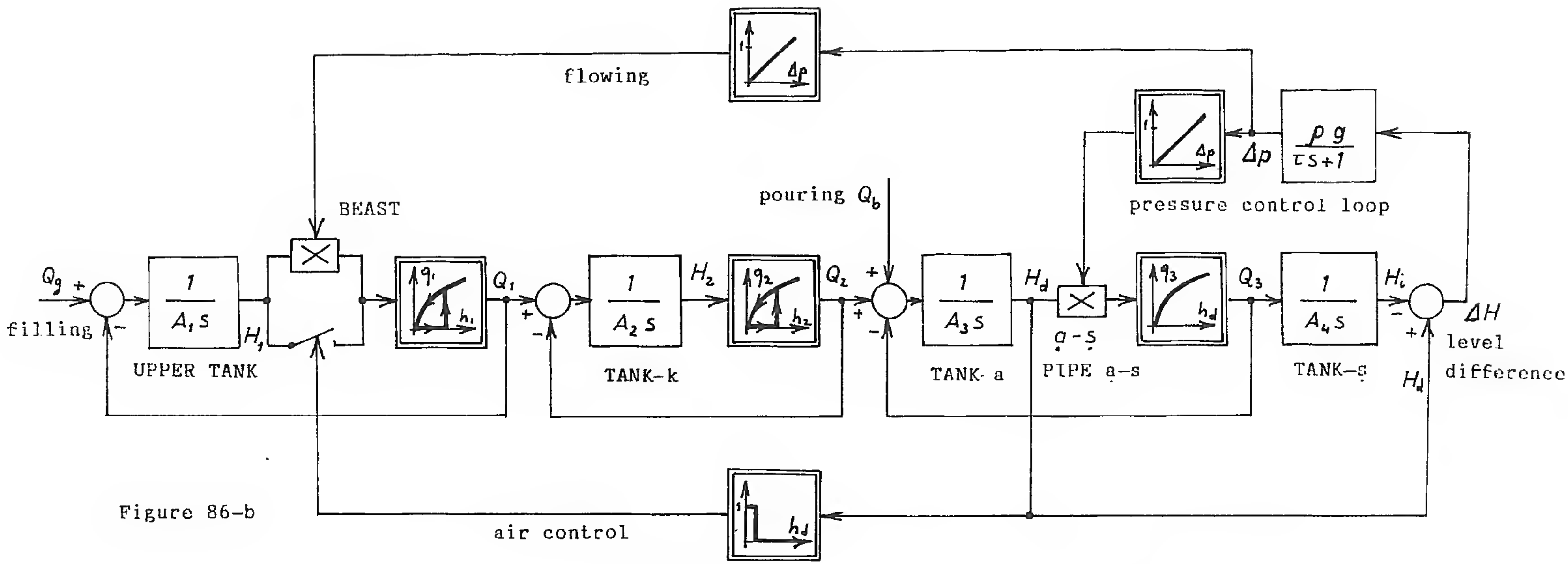


Figure 86-b

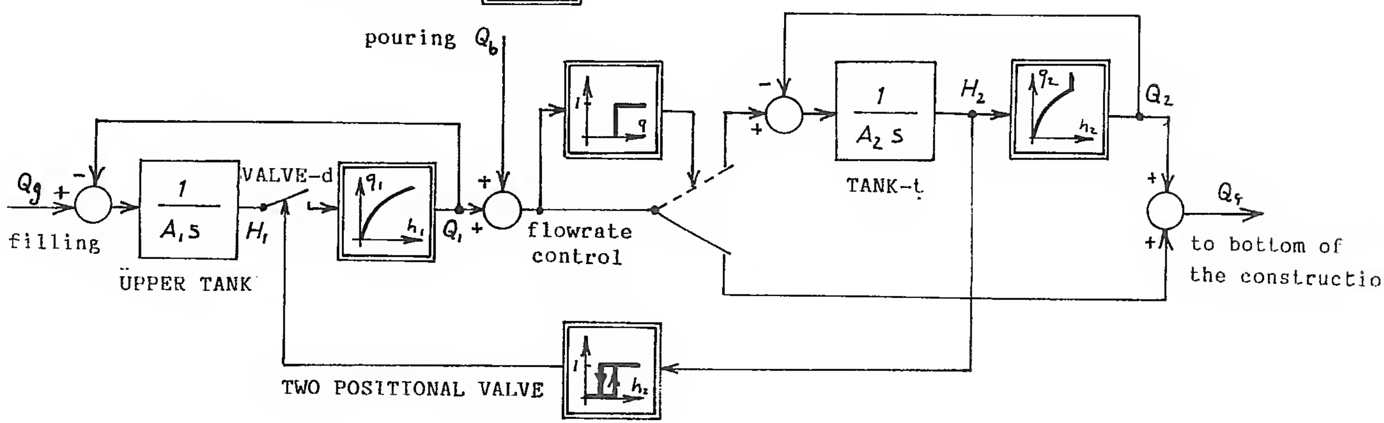


Figure 87-b

Model 88-A Fountain From Which the Water Spurts out in the Shape of a Lily, or in the Shape of a Shield (or Spear) (Figure 88-a)

The water flows from the tank **d** to the fountain body through the pipe **d-b.** The body in the form of a bud is divided in two sections by the partition **z-e.** If the water should shoot out in the shape of a lily (Figure 88-b), a reversed funnel is fixed over the partition **z-e.** The connection between the upper and lower sections is achieved by five pipes **h** which are slightly inclined and attached to the funnel wand. The water entering from **b** into the lower section goes through the pipes **h** to the upper section. Under pressure the water in the upper section throws out revolving first tangent to the funnel and then to the upper end **k** of the bud. At the same time, the water which goes from the lower section into the funnel squirts out from the **a** end of the funnel and falls back in the fountain in form of drops. The water which throws out as a thin round leaf from the end **k** and the water which squirts out like a string from the end **a** of the fountain form together an elegant lily.

If the water which throws out from the pipes **h** attached to the funnel is pressed down by a cover **a** at the end **k** of the bud (Figure 88-c), the water squirts out as a thin rotating membrane and appears like a shield.

At last if the water is spurted out under full pressure only from the end **a**, it heightens a while in thickness of an arm and falls back in drops appearing like a spear (Figure 88-d).

In the following models (see Model 89 to 94) different forms of the above explained fountains are applied.

Model 89-A Fountain Which Shoots Up Water Successively in the Shape of a Lance, or in the Shape of a Shield (Figure 89-a)

The water reaches the fountain from the canal **a.** At the end of the canal, water goes through an overflow pipe preventing hard materials like sand from flowing into the tank **b** which is on the right arm of a two positional balance. Since the arm of the balance is in the form of a pipe, the water following the way **b-d-c** flows into the tank **y.** Because of the level

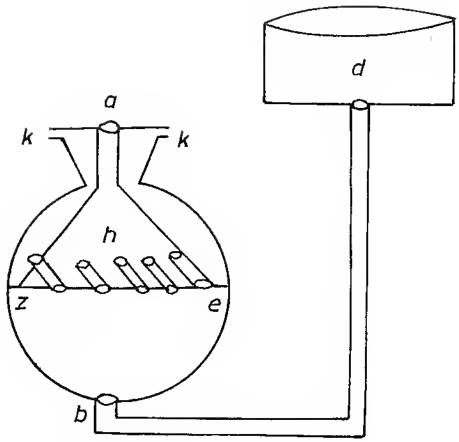
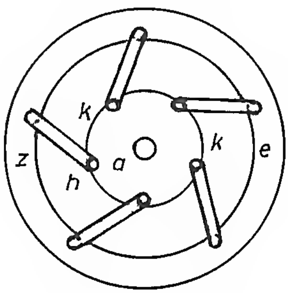
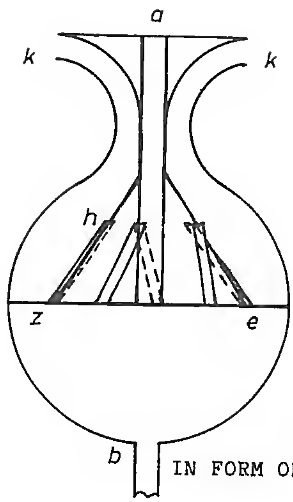


Figure 88—a (T)

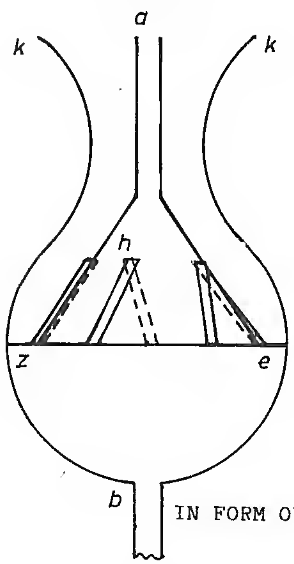


TOP VIEW



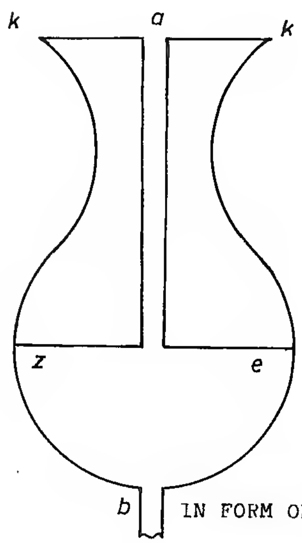
IN FORM OF A SHIELD

Figure 88—c



IN FORM OF A LILY

Figure 88—b

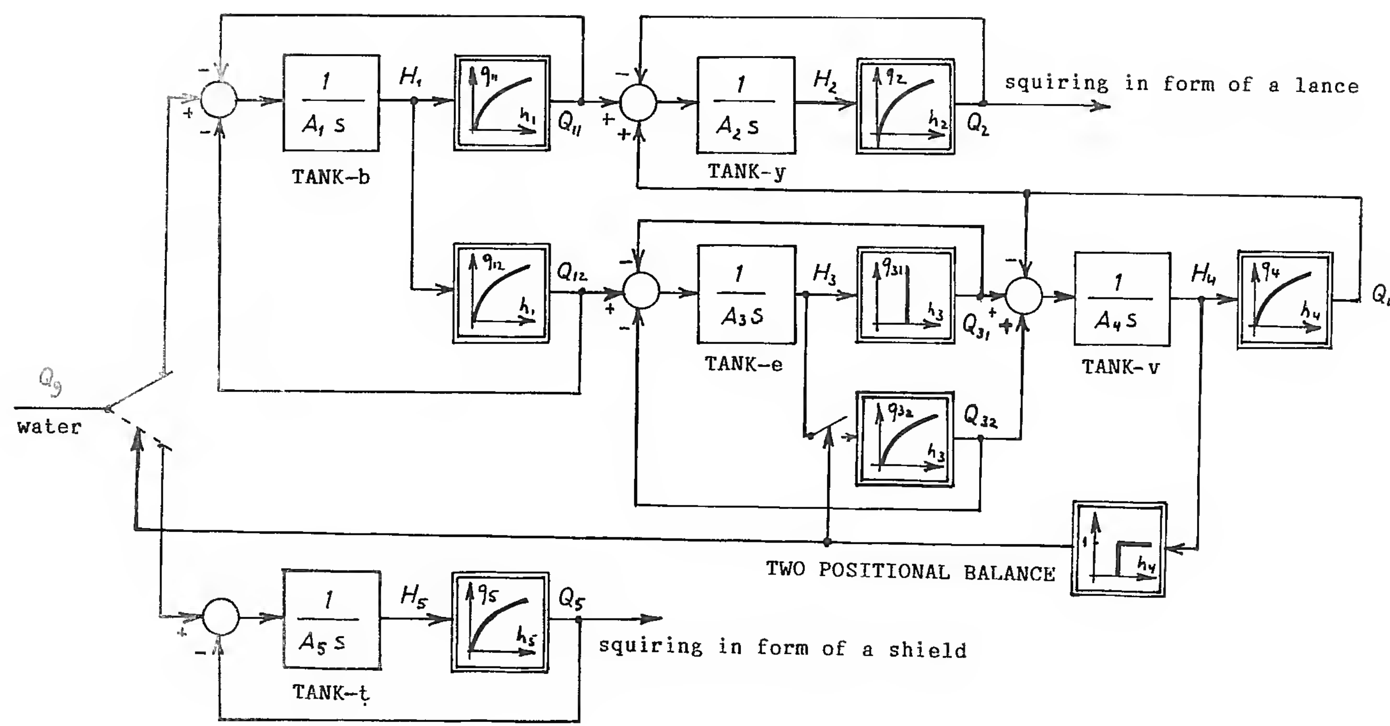


IN FORM OF A SPEAR

Figure 88—d

difference, the water taking the way **k̇-ş** shoots up under pressure from the bud like end of the fountain in the shape of a lance. Some part of water which flows along the pipe **b-d-c** on the arm pours over a little pipe (not shown in the figure) into the tanks **e** and **v** which are bound to the left balance arm by the aid of chains (see Model 91). First the tank **e** fills up, then the water overflows through a hole into the tank **v**. When the level of the water in the tank **v** reaches a certain height the equilibrium of the two positional balance changes and the arm inclines to the left. When the balance inclines the water pouring from the overflowing pipe **a**, begins to flow into the tank **ţ** instead of the tank **b** on the balance arm (to make the movement of the balance arm **c-d-b** possible the distance between the tank **b** and the canal **a** has to be larger than shown in the figure). The water flowing into the tank **ţ** reaches the lower section of the fountain bud under pressure because of the level difference, through the outer pipe **f-ş** and squirts out from the opening **k-ạ** in the shape of a shield, passing the inclined pipes **s** and **l**. When the balance inclines to the left, all the water of the tank **e** on the left balance arm flows into the tank **v**. The water of the tank **v** pours into the tank **y** through a little pipe **v-z**. The balance stays inclined to the left and the fountain squirts out in shape of a shield as long as the tank **v** contains water. When the tank **v** empties the equilibrium of the balance changes again, the arm returns back to its horizontal position and the water squirts out like at the beginning in the shape of a lance. The squirting out of the water from the fountain successively in the shape of lance and shield continues as long as water flows from the canal.

The block diagram of the system is seen in Figure 89-b. The squirting of the water in the shape of lance and shield is realised by a two positional balance (see Motif 8). To achieve a healthy working system, the cross section of the pipes, the dimensions, forms and places of the tanks **e** and **v** have to be selected correctly and the balance has to be balanced carefully.



squiring in form of a lance
squiring in form of a shield
TWO POSITIONAL BALANCE
TANK-b
TANK-y
TANK-e
TANK-v
TANK-t
water

Figure 89-b

Model 90-Another Fountain (see Model 89) **Working by the Flow of Water (or Wing Blow), Shooting Up Water Successively in the Shape of a Lily or a Lance** (Figure 90-a)

The water, which is conducted to the construction by the canal **a**, flows over the wings of a turbine **k̇**, turning on a vertical axle. The poured water flows from the turbine wings into the tank **k-l**, which is on the same axle and turns with it. Proportional to the angular velocity, the water pouring out through the hole **k** on the edge of the tank **k-l**, flows for a while into the tank **c-d** and next into the tank **m-b**. The water flowing into the tank **c-d**, going through the pipe **d-z**, squirts out under pressure, because of the level difference, in the shape of a lance from the bud of the fountain. However, the water flowing into the tank **m-b**, going through the outer pipe **e-v**, flows into the lower section of the fountain bud and under the same pressure going through the inclined pipes **y**, squirts out from the end **h** of the bud in the shape of a lily.

The block diagram of the system is seen in Figure 90-b. The turbine and the turning tank **k-l** with a hole on the bottom, which pours out the water successively in the tanks **c-d** and **m-b** is shown by a turning switch on the block diagram (see Motif 11). It is admitted that the angular velocity ω of the turbine is proportional to the flow rate q_g or $\omega = K\ Q_g$. It is also stated that the axle can be turned by the wind. In this case the movement of the wing axle turned by the wind is transmitted to the vertical turbine axel by a gearing. In this case the water of the canal **a** pours directly into the tank **k-l** which turns together with the turbine axle and has a hole on the bottom.

Model 91-Two Fountains Which, Mutually and Periodically Changing, Shoot Up Water in the Shape of a Lance or in the Shape of a Shield (Figure 91-a)

This system, which is a double version of the system 89 similarly contains a two positional balance, the tip up time of the balance regulating tanks **e** and **v**, the water distributing tanks **y** and **ţ**, and two fountains. The water which pours from the canal (not shown in the figure) flows into the tank **b** over the right arm of the balance. From this tank the water flows over the pipe **b-ş-c** stretching along the balance arm into the tank

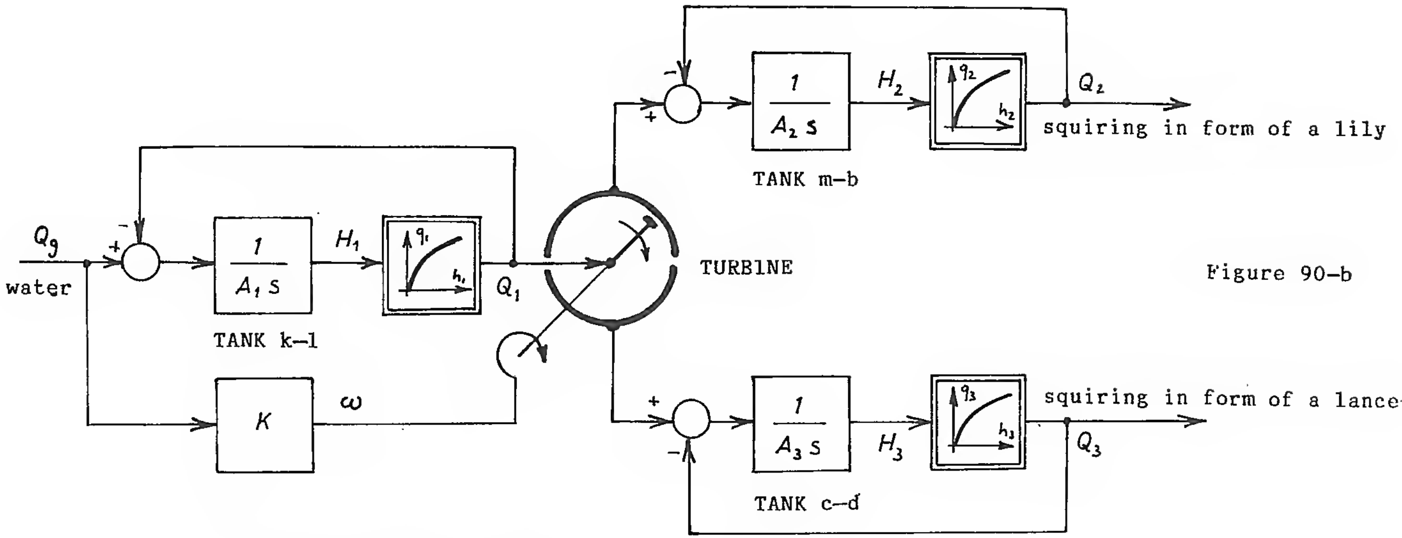


Figure 90–b

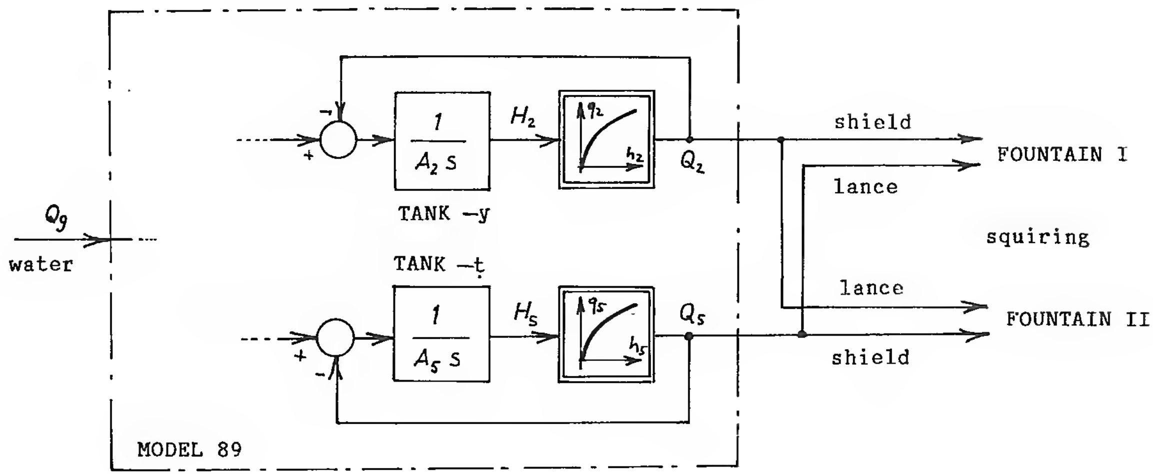


Figure 91-b

y and from there shoots up going through the pipe **k̇-f** from the right fountain in the shape of a lance, through the pipe **z-d** from the left fountain in the shape of a shield.

A part of the water which flows through the balance arm goes into the tank **e** which is tied to the left balance arm. When the tank **e** fills the equilibrium of the balance changes and the balance arm inclines to the left. At this stage, the water pours from the canal into the tank **ţ** and from there flowing through the **pipe m-b** shoots up from the right fountain in the shape of a shield; and flowing through the pipe **l-d** shoots up from the left fountain in the shape of a lance. When the balance inclines, the water of the tank **e** flows into the tank **v** and from there begins to pour into the tank **y**. When the tank **v** empties the balance returns back to its first position, and the above procedure repeats as long as water pours from the canal into the system.

The block diagram of the system given in Figure 91-b is different from the block diagram of the Model 89 in regard to the water transmission to the fountains. The water which shoots up from the Fountain I in the shape of a shield is supplied from the tank **y** and in the shape of a lance from the tank **ţ**; and the water which shoots up from the Fountain II in the shape of a lance is supplied from the tank **y**, and in the shape of a shield from the tank **ţ**.

Model 92-Another Fountain (see Model 89 and 90) **Which Shoots Up Water Successively in Different Shapes** (Figure 92-a)

Being also the subject of the Models 89 and 90, the construction of a fountain which shoots up water successively in different shapes is solved here interestingly by applying similar motifs in an almost modern design. In Figure 92-b a reconstruction of the model is given in accord with the text, since the original figure is incomplete and wrong. In this model, the mechanism which regulates the shape of the up-shooting water, takes in the fountain bud. The shooting modification is realised in Model 89 by a balance with two positions and in Model 90 by a tank with a hole which turns by means of a water turbine on the same axel. A water turbine is also used in the realisation of this model. The water which is transmitted to the fountain bud under pressure goes through

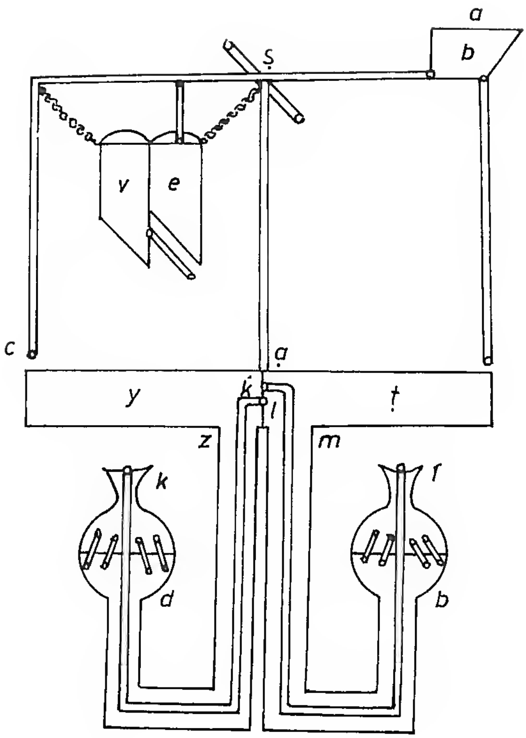


Figure 91–a (B)

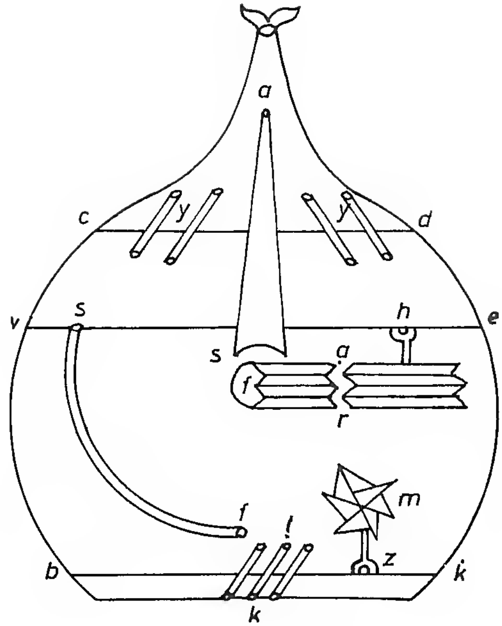


Figure 92–a (B)

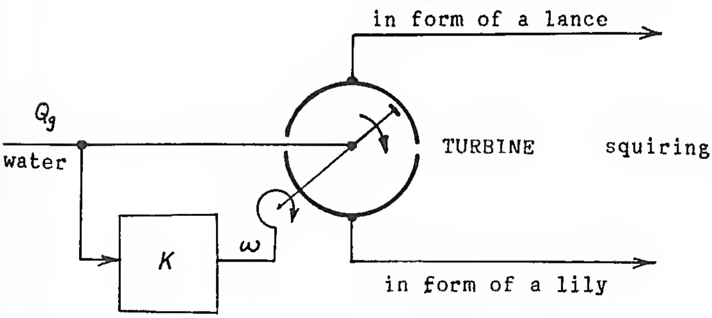
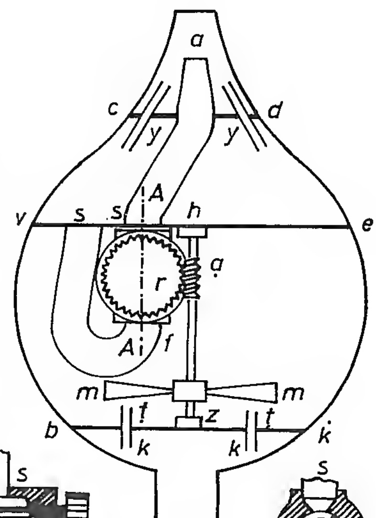
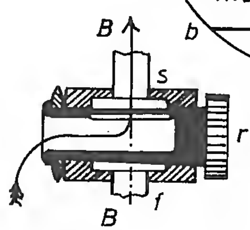


Figure 92–c





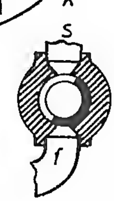


Figure 92–b

cross-section A–A

cross-section B–B

the little pipes **k** and spurts on the wings **m-m** of a turbine which is over a vertical axel **z-h**. A worm screw **a** on the same axel **z-h** turns the gear **r** and the hole navel **s-f** which is tied to it (see Figure 92-b, the cross section A-A). The water enters the navel from the opposite side of the gear **r** and goes according to the navel position, into the pipes **s-a** or **f-s** through a gap opened along the half circumference of the navel (see Figure 92-b, the cross section B-B). Thus, the water shoots out in the shape of a lance when it flows through the pipe **s-a**, and shoots out in the shape of a lily when it flows through the pipe **f-s** and the little pipes **y** (see Figure 88-b).

The block diagram of the system is given in Figure 92-c. In this model, as in system 90, it is admitted that the turbine turns proportional to the flowrate q_b of the water.

Model 93-A Major and Two Minor Fountains Which Changing Mutually and Periodically, Shoot up Water in the Shape of a Lance or a Shield (Figure 93-a)

The operation principle of this system is identical to Model 92. The water turbine and the gears are in the bud of the major fountain (see Figure 92-b). The water is transmitted under pressure into the partition **k** of the fountain bud and flowing through the little pipes **k-t** turns the turbine **m**. Thus, the worm screw on the axel **z-m** turns the gear **f** and the hole navel connected to it. The water goes for sometime from the turbine partition through the pipe **s-h** into the middle partition **h-z**, and for another time through the pipe **b-v** into the peripheral partition **l-c-d**. From the middle partition, following the pipe **h-a**, the water shoots up through the major fountain in the shape of a lance, and from the minor fountains, following the pipes **h-a** and **z-k**, in the shape of a shield. The water of the peripheral partition **l-c-d** shoots up through the major fountain in the shape of a shield (in the original figure the squirting pipes are not shown); and from the minor fountains following the pipes **l-y** and **l-m** in the shape of a lance.

The block diagram of the system is shown in Figure 93-b.

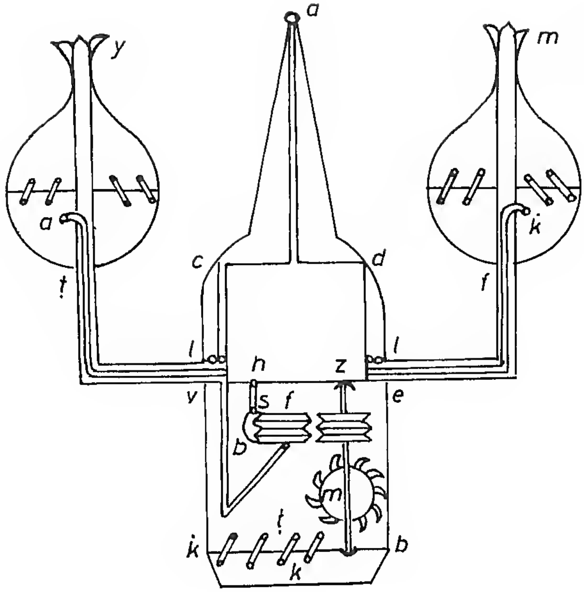


Figure 93—a (B)

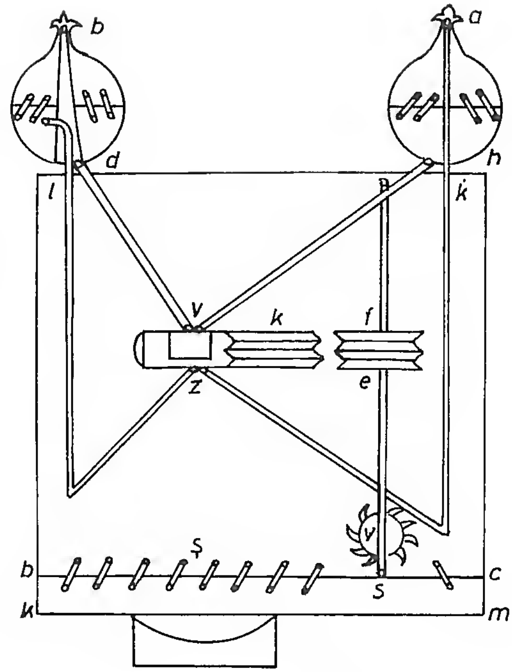


Figure 94—a (B)

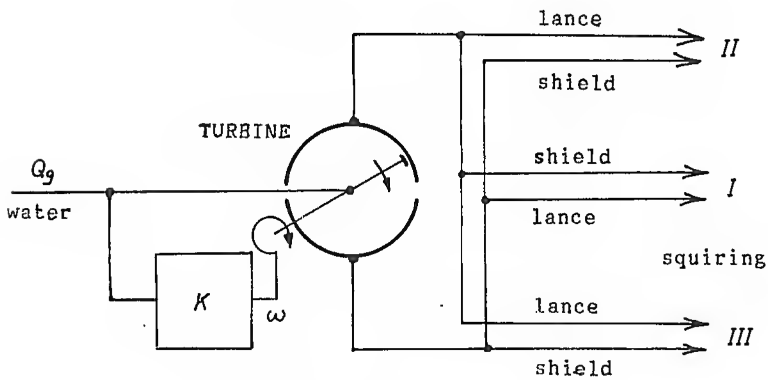


Figure 93—b

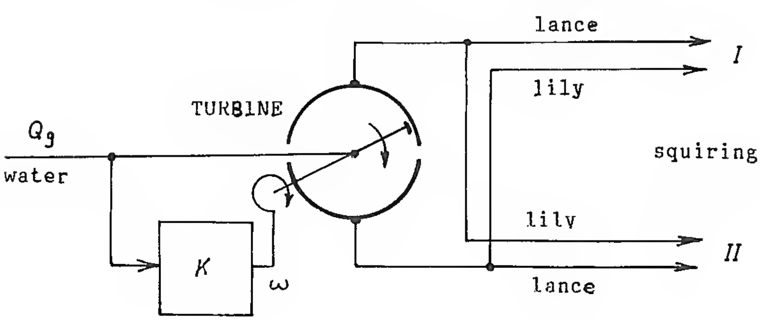


Figure 94—b

Model 94-Two Other Fountains (see Model 91) **Which Changing Mutually and Periodically Shoots Up Water in The Shape of a Lance or Lily** (Figure 94-a)

Being a double version of the system 92, the turbine and the gears are placed in a special tank beneath the fountain buds. The water which is under pressure transmitted to the tank by means of a pipe, goes through the pipes ş and turns the water turbine **v**. The worm screw **f-c** over the turbine axel turns the screw **k** and the navel **v-z** connected to it. When the water of the tank is connected to the **v** side of the navel **v-z** (see Figure 92-b), the water flowing through the pipe **v-d** shoots up from the left fountain in the shape of a lance and through the pipe **v-h** from the right fountain in the shape of a lily. If the water flowing of the tank is connected to the **z** side of the navel, the water flowing through the pipe **z-l** shoots up from the left fountain in the shape of a lily and through the pipe **z-k**, from the right fontain in the shape of a lance.

The block diagram of the system is given in Figure 94-b.

Model 95-An Oil Lamp in Which the Oil Level is Automatically Controlled (Figure 95-a)

The oil lamp over the pillar **l-v** is composed by a spherical oil tank and a vessel **h-a** in which the wick ṭ absorbs the oil. For a complete burning and continuous light intensity the oil level of the vessel **h-a** has to be controlled. The oil is poured into the oil tank through the hole **d**. The poured oil passing the air obstacle **d-b-c** (see Motif 7) gathers on the bottom of the spherical oil tank. During the filling process, the air goes out through the pipe **l-e**. As it is noted in the work, the hole **z** is closed at the beginning or a siphon takes place at the rear (added to the figure by broken lines). If, during the filling operation the hole **z** is closed by means of a wire, for example, at the end of the filling operation this obstacle has to be removed in order to let the oil flow into the wick vessel. If the hole **z** is connected to the oil tank over a siphon, the oil begins to flow spontaneously to the wick vessel **h-a** as soon as the oil in the tank reaches the upper end of the siphon. The oil in the vessel **h-a** rises till the end **e** of the air entrance pipe **e-l** of the tank is covered by oil. Thus, as much as the quantity of the oil burned in the vessel **h-a**, air enters into the oil tank and supplying oil flows out through the siphon and the hole **z**. The automatic control of the oil lamp level continues as long as there is oil in the oil tank.

The block diagram of the system is given in Figure 95-b. The automatic oil supply which is determined by the level difference $\varepsilon = h_r - h_c$ has in regards of the oil viscosity an hysteresis. In the block diagram this particularity is evaluated in the air control block beside the control switch.

Model 96-An Oil Lamp in Which the Wick is Regulated Automatically (Figure 96-a)

The oil lamp is composed of an oil pot in which the wick **t** burns, and a reflector (which may be a mirror) attached over a pillar used to take the lamp. The oil is poured into the pot through the hole ạ. The float s in the pot rises with the oil level. A chain attached to the float s stretches over two pulleys and ends in a little iron weight l whose mass is smaller that that of the float. Over the second horizontal pulley axle **e-b-a**, there exists also a gear **a** (in the figure axle **e-b-a** is turned into the figure plane, this is, apparently, the reason for the strange form of the pot cover). Thus, when the float s rises, the gear **a** which is over the turning axle **e-b-a**, slides the wick which holds a quarter of a circle long curved and toothed bar in the direction **c-k**. When the oil vessel is full, the length of the wick ṭ has to be enough to go out from the vessel edge. With the burning of the lamp or the consuming of the vessel oil, the float decreases and the gears move the wick bar in the direction **v-ṭ**. By this mechanism the burned quantity of wick is replaced automatically (see the reconstruction Figure 97-b).

The block diagram of the system is given in Figure 96-b. The shove, proportional to the decrease of the oil level has to be equal to the length of the burned wick. As it is seen from the block diagram, the system is an open loop control system. In the block diagram **r** being the radius of the pulley and **h** the oil level, the gear position Θ is given by $\Theta = h/r$. The shove **x** of the wick is accepted to be proportional to the gear position: $x = k\,\Theta$.

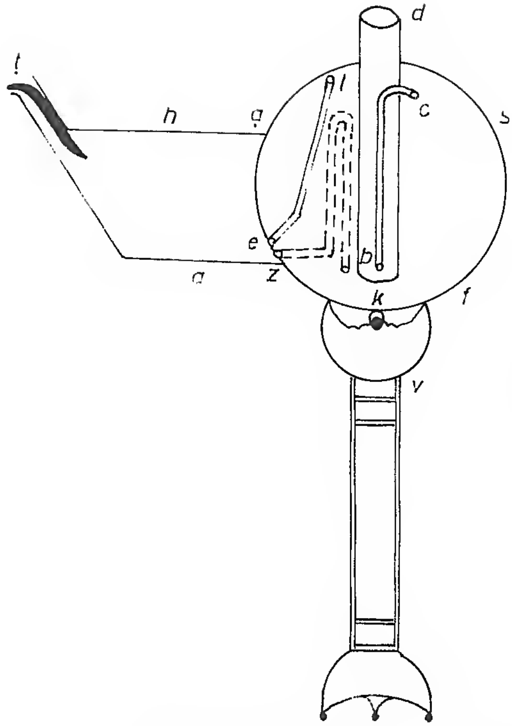


Figure 95-a (B)

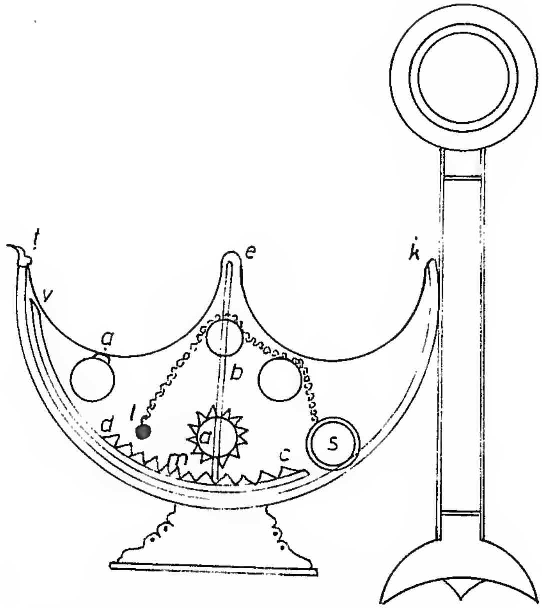


Figure 96-a (B)

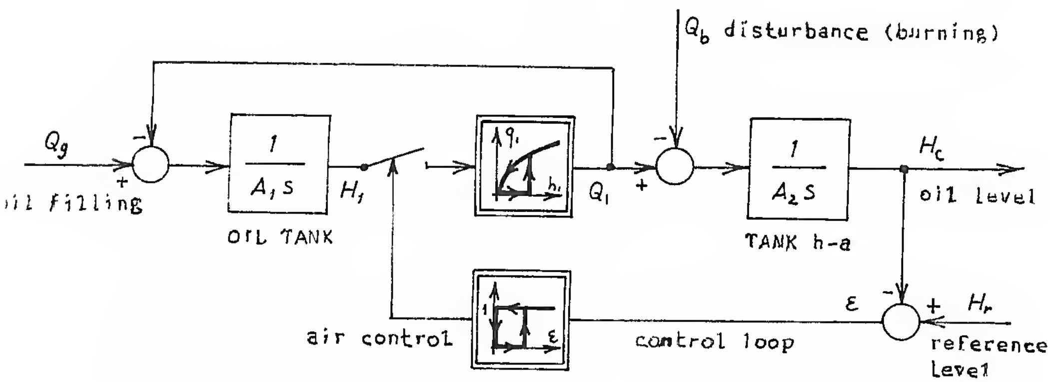


Figure 95-b

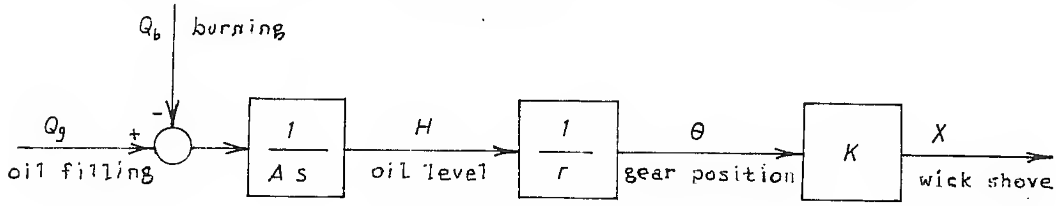


Figure 96-b

Model 97-An Oil Lamp in Which the Wick is Automatically Regulated and the Oil Level is Automatically Controlled (Figure 97-a)

Here, the oil level control of the Model 95 and the automatically regulated wick mechanism of the Model 96 are applied together in the same model. Since the original figure is inadequate a reconstruction attempt is given in Figure 97-b. The oil is poured through the hole **l** into the tank behind the lamp. The inpoured oil passing the air obstacle **v-z** flows into the oil tank and from there into the lamp vessel going through a swan head **a-e** stretching over the oil lamp. The oil level of the vessel is automatically controlled by an air pipe (also from which the wick regulating chain goes through). The flow of the oil into the lamp vessel stops when the end **c** of the air pipe is blocked by the oil. The burned quantity of oil is automatically refilled by the tank oil flowing through the swan head (see Model 95)

The wick is regulated by the float **ṭ** existing in the oil tank. The position of the float is transmitted by the pulleys **h-c-ḳ** and the counter weight **s** to the gear axel **y-ḳ**. As in the Model 96 the gear **y** moves the wick towards the outlet hole when the level of oil in the tank decreases.

As seen in Figure 97-c the block diagram of the system is formed by the combination of the previous system block diagrams. In the work it is also stated that this system can be used as a time piece. A mechanism connected to the float **ṭ** lets a marble ball fall every hour, so that the time is then determined by the number of the fallen marbles.

Model 98-An Oil Lamp Which Does Not Extinguish by Always Keeping its Back to the Wind (Figure 98-a)

The oil lamp **l** is tied to a half cylindric plate which protects the lamp from the wind. In the original figure the lamp is drawn too long and too high. The plate is fixed to the pillar **k-z-e** by means of the bearings **h** and **ṭ**. In order to turn the back of the plate always against the wind, a triangular wing **h-a-y** is attached to the plate (in the original figure the wing is incorrectly drawn attached to the pillar, the true position is shown by broken lines).

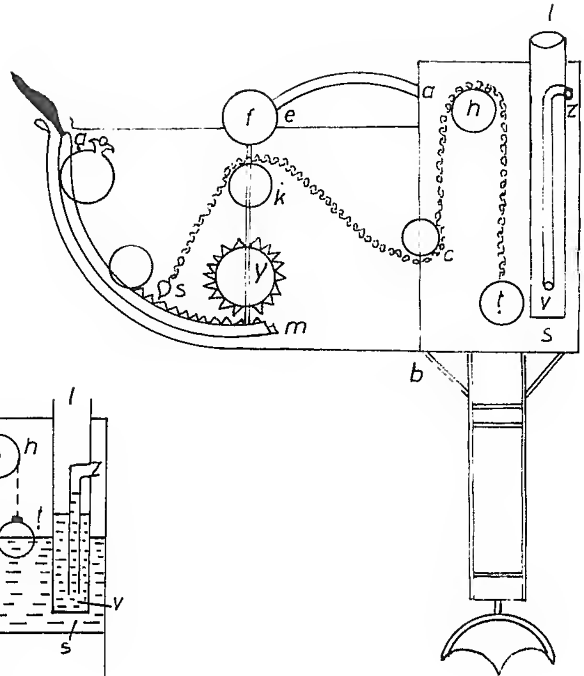


Figure 97-a (B)

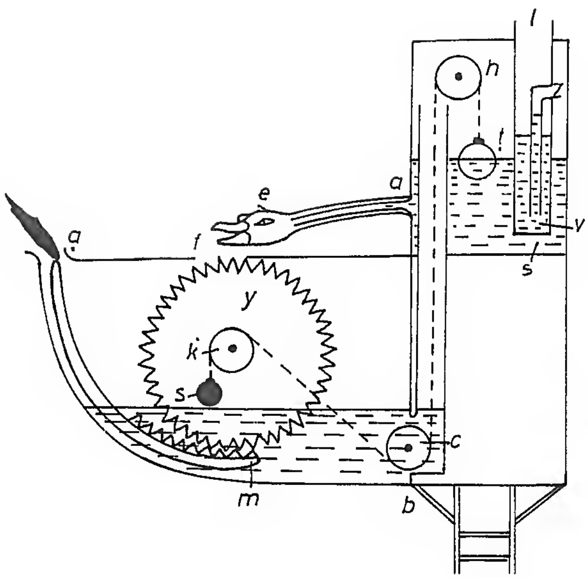


Figure 97-b

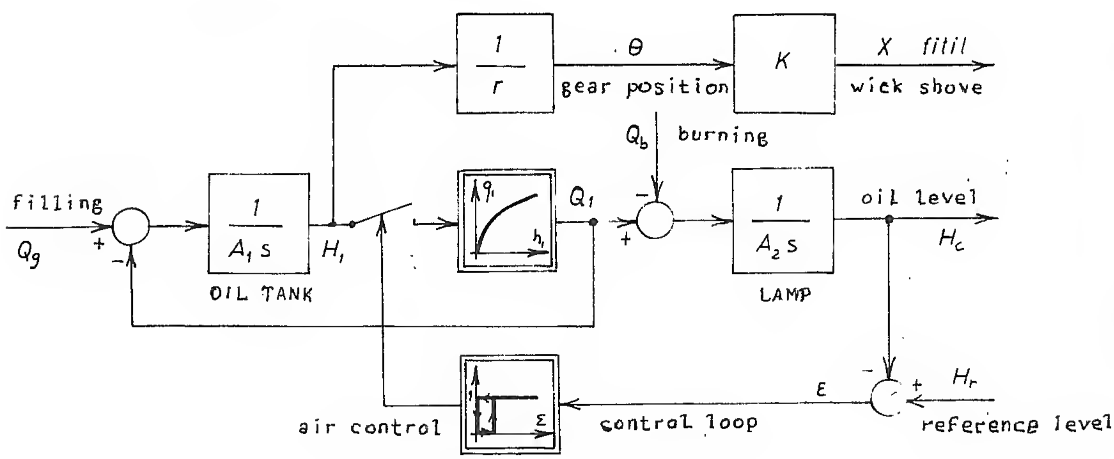


Figure 97-c

The wind power F being a variable, the moment generated by the wind is given as

$$T = F \cdot \frac{2}{3} \cdot l \cdot \sin(\Theta_r - \Theta_c)$$

In this formulation, the triangular wing length is given by l, the wind and lamp directions are determined by the angles Θ_r and Θ_c. For small angle differences $\Delta\Theta = \Theta_r - \Theta_c$ the approximation

$$T = F \cdot \frac{2}{3} \cdot l \cdot \Delta\Theta$$

is valid, J being the moment of inertia and B the friction coefficient of the lamp, the moment equation is given as

$$T = J . \frac{d^2\Theta_c}{dt^2} + B . \frac{d\Theta_c}{dt}$$

and the block diagram seen in Figure 98-b is obtained. The wind direction Θ_r gives the reference of the automatic control system. When the wind power F is constant, being no more an input variable, it is evaluated like a coefficient in the first block of the block diagram. The natural frequency and the damping ratio of the system are computed as

$$\omega_n = \sqrt{\frac{2Fl}{3J}} \quad \text{and} \quad \xi = B\sqrt{\frac{3}{8FJ}}$$

Model 99-A Bellow Which Blows Air in Wells (Figure 99-a)

This is a bellow used in dangerous wells in which oxygen is insufficient or poisonous gases exist. The person descending the well which in the figure is shown by the rectangle **a-b-c-d**, holds the end **e** of the trunk

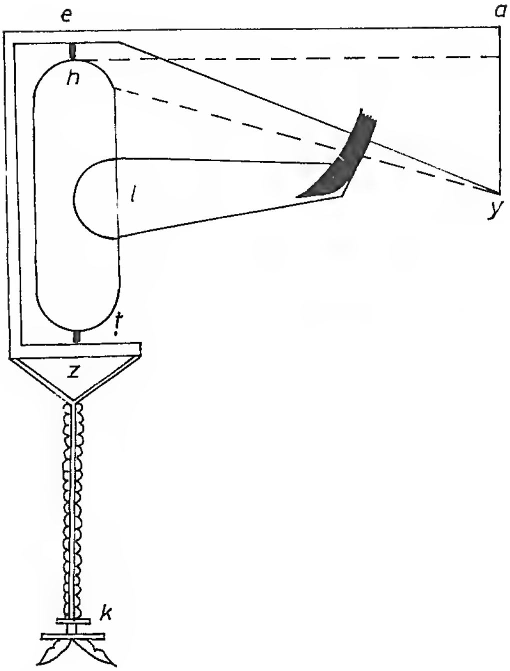


Figure 98-a (B)

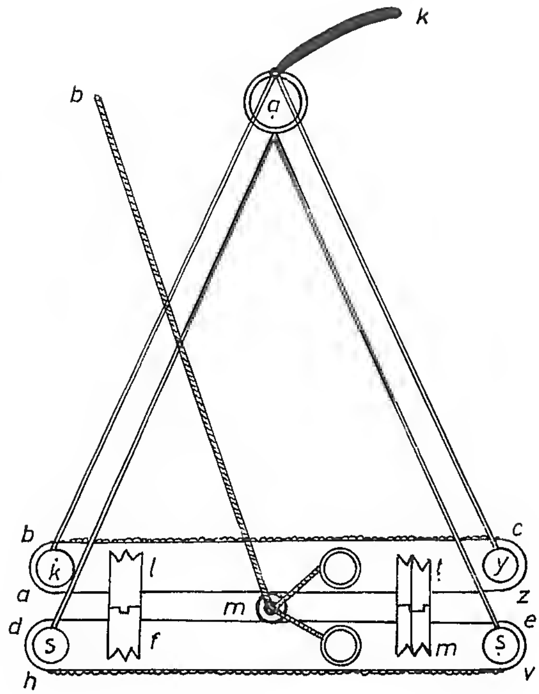
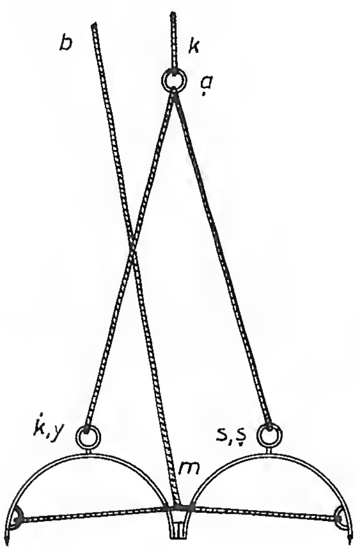
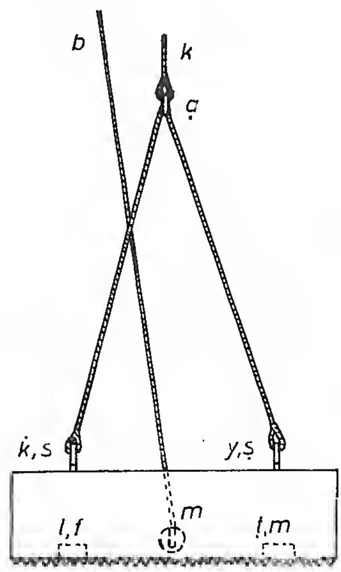


Figure 100-a (B)



end-view

Figure 100-b



side-view

Figure 100-c

v-e on his mouth and nose level. The bellow on the end **v** of the trunk is operated by a second person outside of the well (see the reconstruction given in Figure 99-b). The person on the outside pulls and pushes the arm **h** of the bellow in equal intervals. During the pulling operation, because of the pressure difference, the valve **v** on the trunk side of the bellow closes and fresh air enters into the bellow through the open valve **z**. At the push operation the valve **z** closes and the valve **v** opens for the same reason, so that the fresh air is pushed towards the trunk end **e** where the person works in the well.

The block diagram of the system is given in Figure 99- The sucking and blowing action of the bellow depends on the sign of the velocity v which is the derivative of the reference position x_r. The signals controlling the valves **z** and **v** are derived from the same signal $v = \dot{x}_r$ with the difference of negation. The input and output flowrates q_g and $q_ç$ are proportional to the position differences $\Delta x = x_r - x$

$$q_g = k_1 \Delta x \quad , \quad q_ç = -k_2 \Delta x$$

(here k_1 and k_2 are proportionality coefficients).

Moreover the variation of the stored air in the bellow or $\Delta q = q_g - q_ç$ is proportional to the opening and closing velocity

$$\Delta q = A . \frac{dx}{dt}$$

A being the sectional area of the bellow.

Model 100-A Scoop Which Serves to Extract Materials From the Sea (Figure 100-a)

The reconstruction of the scoop formed by two half cylinders tied together by the hinges **l-f** and **ţ-m** is shown as end-and side-view in Figures 100-b and c. The scoop is brought over the material to be extracted from the sea in open position (see Figure 100-b) by means of the rope **k** fastened to the rings **k̇, y, s** and **ş** over the intermediary

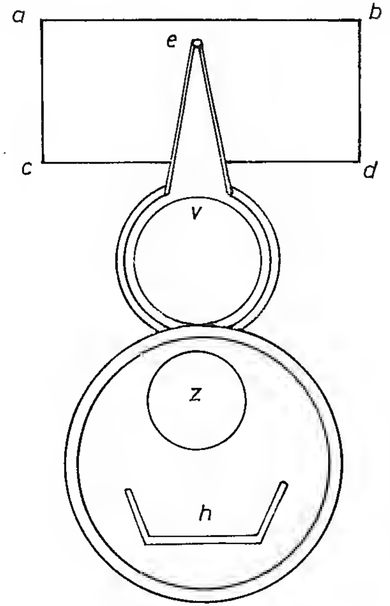


Figure 99—a (B)

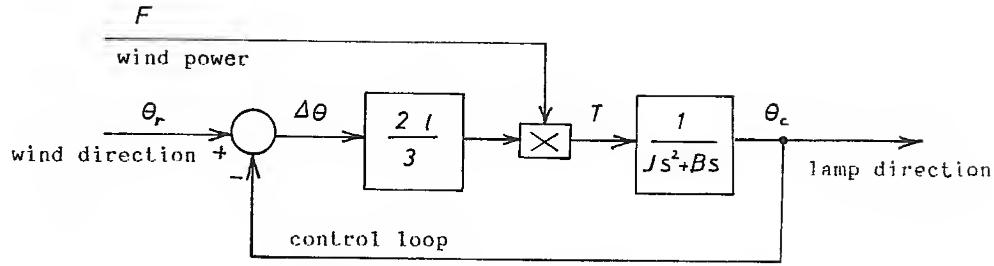


Figure 98—b

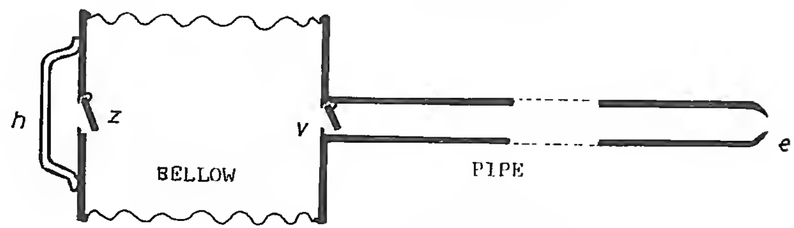


Figure 99—b

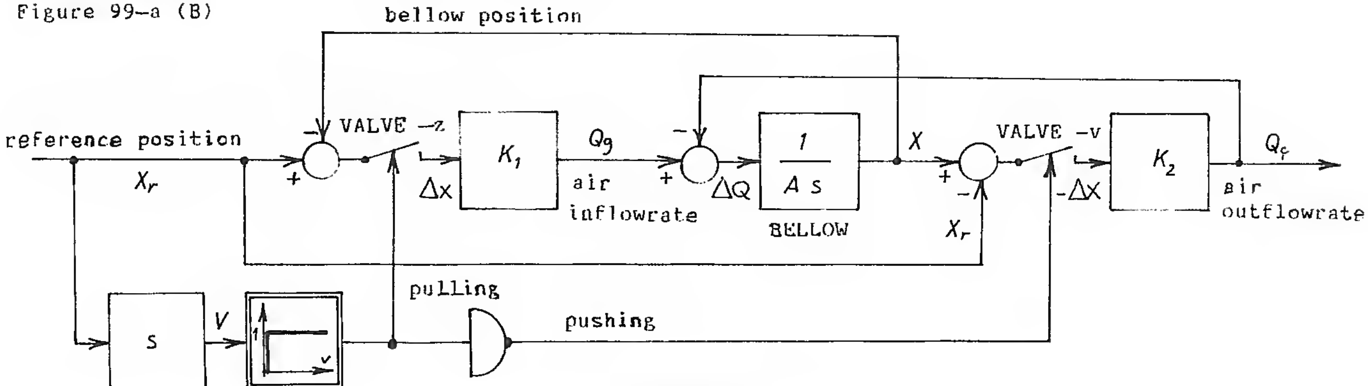


Figure 99—c

ring ą. During descending the rope **b-m** which is fastened to the inner rings of the scoop's arm through the hole **m** are left free. In a second, movement the rope **b-m** is pulled and the required material is brought into the scoop cylinder or between the teeth of the arms. At last in the third movement the scoop is kept closed by the rope **b-m** stretched and taken out from the sea by means of the rope **k**. To empty the scoop outside of the water, the rope **b-m** has to be left free. It is stated in the work that the scoop is suitable to extract pearls from the sea.

Model A-1-A Fountain Which is Operated by an "Elevation Tank" (Figure Al-a)

The water is transmitted to the fountain through the pipe **ţ-m**. However, an obstacle exists between the pipe end **m** and the spurting end s of the fountain, shown by **z** in the figure, so that the pressure of the water in the pipe is not enough to surpass it (in the figure the pipe **ţ-m** and the end s of the fountain are drawn one over the other). In this model, which brings a solution to this problem, the water of the pipe **ţ-m** flows first into the tank **m-ţ-y** where the hard materials subside. The water flows from this tank into the elevation tank **a-b-c** through the pipe **y-b**. This elongated tank is higher than the obstacle level **z**. In the elevation tank there is a siphon **c-d-f** having the same length. The outflow of the siphon is connected to the fountain by a lead pipe **c-z-h-s**. When the tap ş is open the water flows first into the subsiding tank and secondly enters into the elevation tank through the pipe **y-b**. But, since the pressure of the water is insufficient, the flow of the water ceases, after reaching a certain level in the elevation tank. Then, the tap ş is closed and water is poured into the elevation tank through the cover **a**. When the level of the water in the elevation tank reaches the upper end of the siphon, the water begins to spurt out from the fountain and the tap ş is again opened. Since the cross-section of the siphon is inferior to that of the pipe **y-b** the elevation tank does not empty as long as the tap ş is open.

As seen from the block diagram given in Figure Al-b, this system operates by means of a siphon. The level difference necessary for the operation of the siphon is obtained by the water poured from the outside into the elevation tank. In the original figure the line drawn between the obstacle **z** and the end **d** of the siphon (drawn in broken line) determine

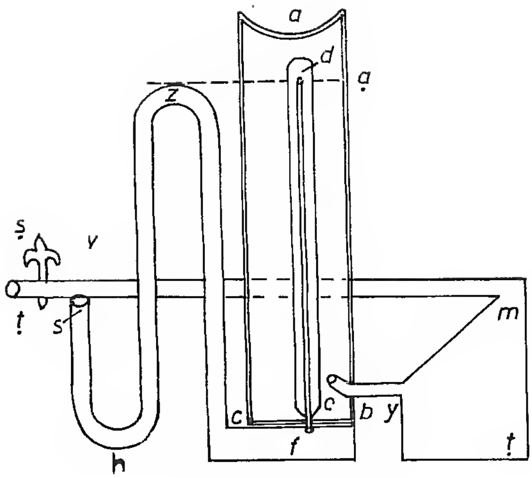


Figure A1-a (V)

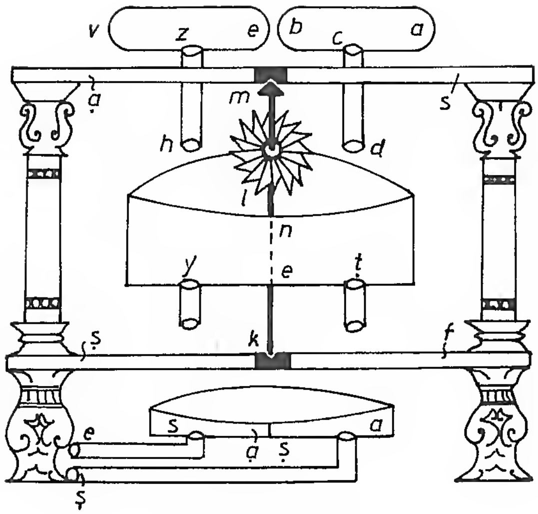


Figure A2-a (T)

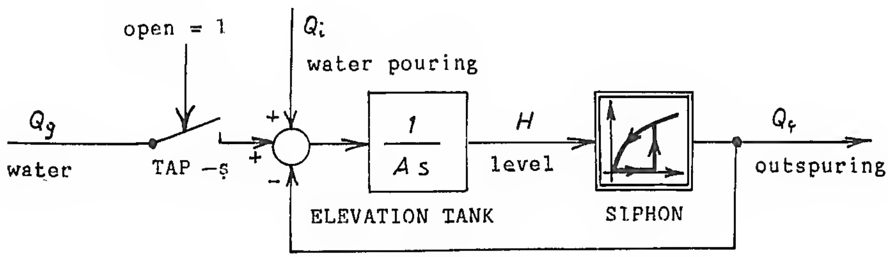


Figure A1-b

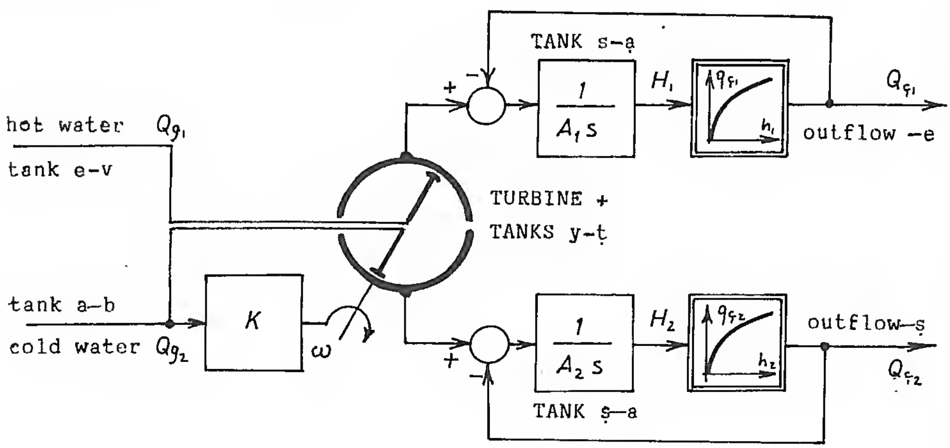


Figure A2-b

the relation between the height of the obstacle **z** and the length of the siphon. However, the surpassing of the obstacle **z**, primarily depends on the height of the water filled into the elevation tank and not on the length of the siphon.

Model A-2-A Construction With Two Outlets Which, Changing Mutually and Periodically, Pours out Hot and Cold Waters (Figure A2-a)

This construction is foreseen to be used in baths. The hot water is conducted to this system from the tank **v-e** through the pipe **z-h** and the cold water from the tank **b-a** through the pipe **c-d**. The cold water is poured from the end **d** of the pipe **c-d** over the wings of the turbine **l** (see Motif 11). On the axle **m-k** of the turbine exists a cylindrical tank **y-ţ** divided by the partition **n-e** into two equal parts. Thus, the cold water which pours over the wings of the turbine and turns the axel flows periodically, according to the position of the tank **y-ţ**, into the tanks **ţ** or **y**. The hot water pouring from the pipe **z-h** directly into the tank **y-ţ**, flows always in the other half of the tank (in the figure the pipe **c-d** is drawn too far on the right of the turbine, in this position the water pouring from the pipe **c-d** cannot turn the turbine **l**). The cold and warm waters flow from the pipes **y** and **ţ** at the bottom of the partitions into the tanks s-**ạ**. Thus, from the outflows **e** and **ş**, changing mutually and periodically cold and warm waters flow out.

The block diagram of the system is seen in Figure A2-b. In the diagram, the turbine and the tank **y-ţ** which pours out hot and cold water mutually and periodically is shown by a different symbol resembling that of Motif 11. In the work it is stated that this model is used in baths. But, since hot and cold water changes mutually and periodically, this model is apparently only used to obtain lukewarm water.

Model A-3-A Bird Which Discharges From His Mouth the Same Quantity of Water as Poured into the Vessel in Front of It (Figure A3-a)

This is a simplified model or a rough draft of the system given in Model 86. The water is filled into the construction behind the bird through

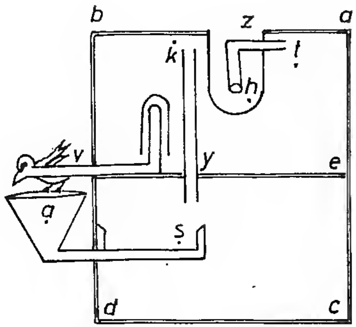


Figure A3-a (L)

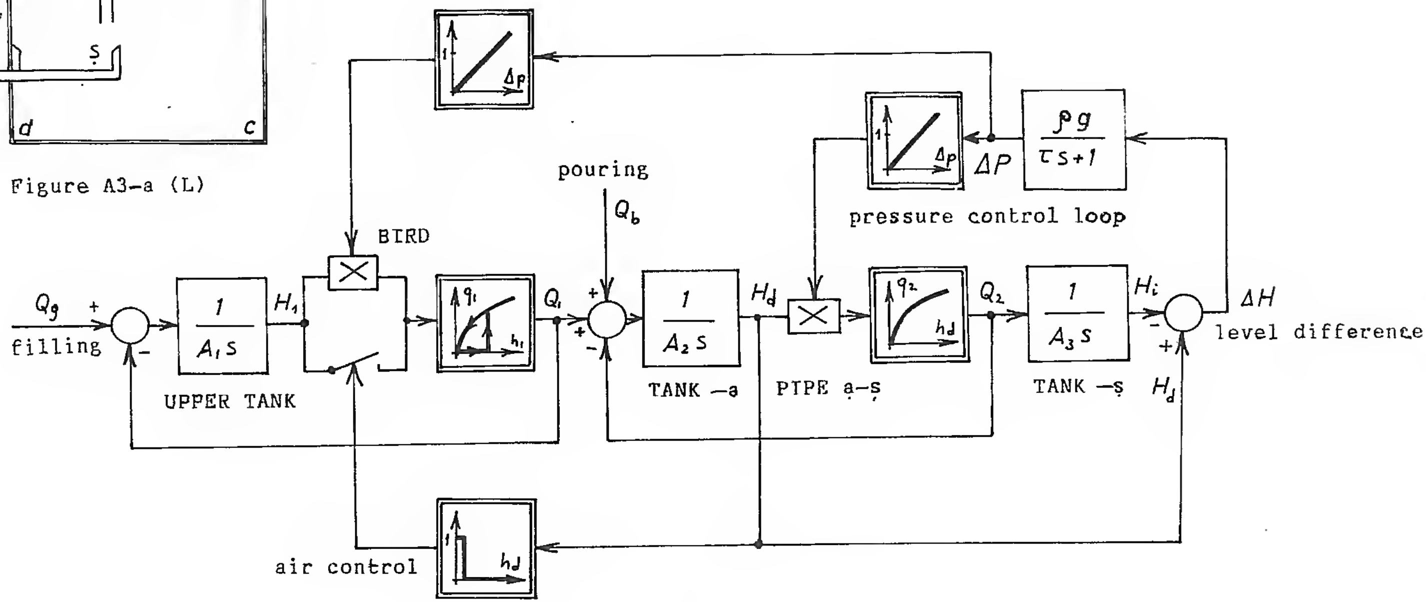


Figure A3-b

the air obstacle z-ḫ-ṭ (in the figure the air obstacle has to be elongated to the bottom of the upper tank). With the rising of the water in the upper tank the air goes out through the pipe k̇-y and the bird siphon v. When the water in the tank reaches the upper end of the siphon the water begins to flow through the mouth of the bird v into the vessel ạ and through the pipe ạ-ş into the tank ş (in the original figure the tank ş is drawn incorrectly, see and compare with figure 86-a). But, since the lower tank is now prevented from the air entrance, the flow of the water to the lower tank through the bird's mouth ceases and the filling operation ends. If, a quantity of water is poured into the vessel in front of the bird (this water does not have to be hot as stated in the work), because of the additional pressure caused by this water in tank ş, the pressure equilibrium of the upper and under tanks, connected by the pipe k̇-y changes. A quantity of water proportional to that poured into the vessel ạ is pushed out through the siphon and the beak of the bird, till a new pressure equilibrium is reached in the system. This effect repeats each time when water is poured into the vessel ạ.

The block diagram of the system based on the hydraulic and pneumatic pressure equilibrium is given in figure A3-b. The effect of the level difference $\Delta h = h_d - h_i$ to the pressure difference Δp is accepted to be of first degree. Moreover, the effect of the pressure difference Δp to the free outflow of the water is taken as linear.

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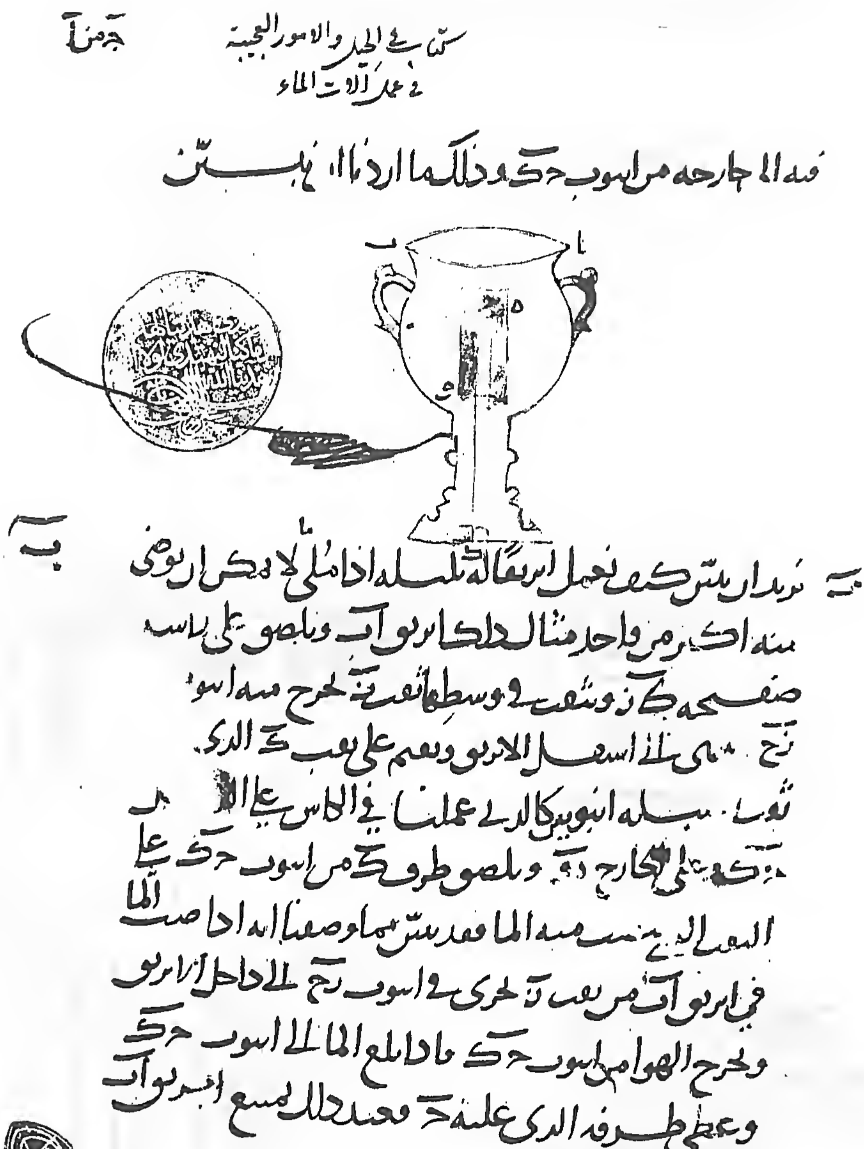

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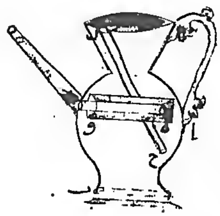

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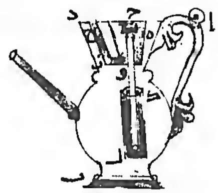

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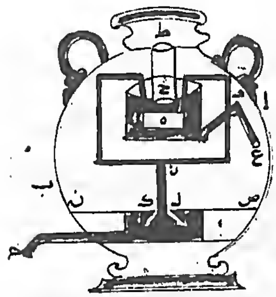

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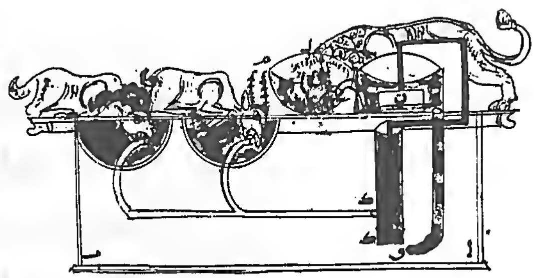

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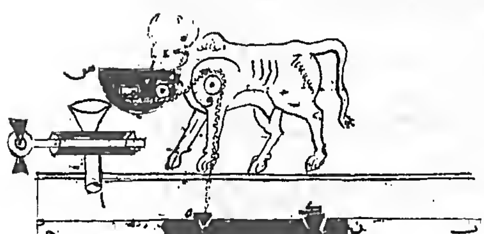

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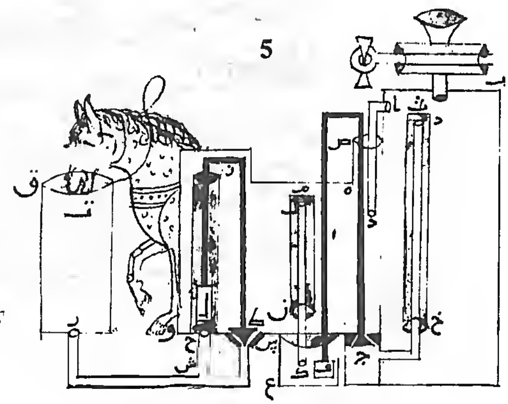

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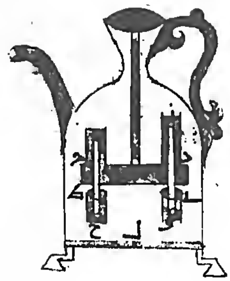

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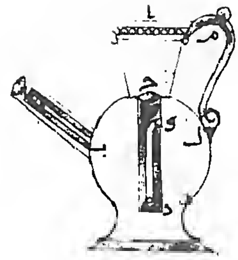

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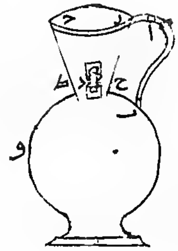

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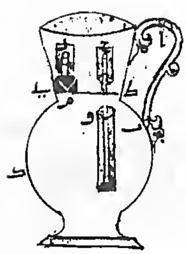

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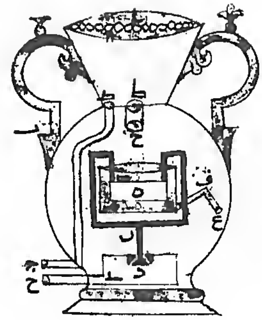

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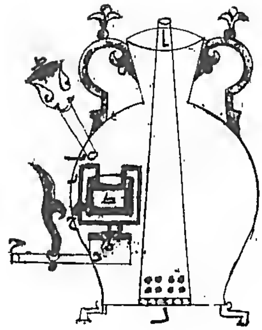

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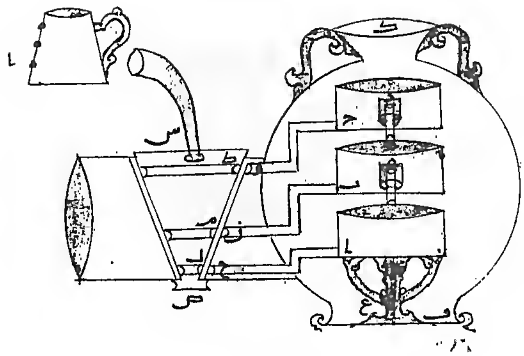

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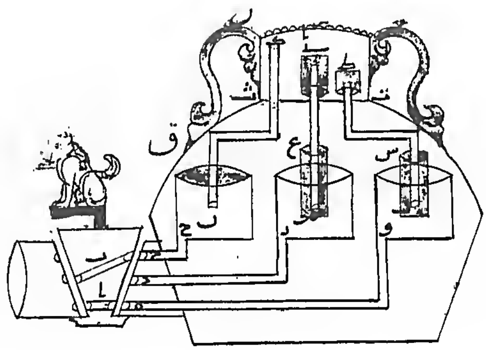

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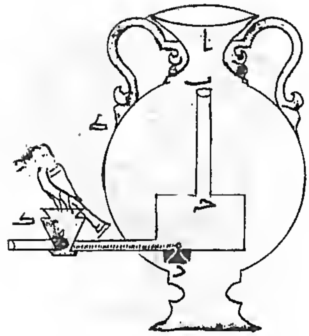

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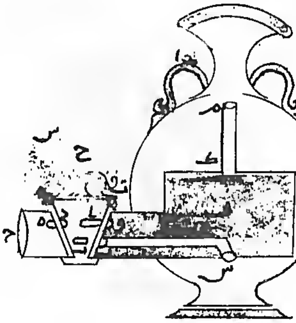

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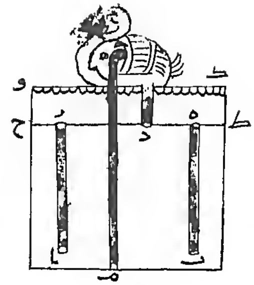

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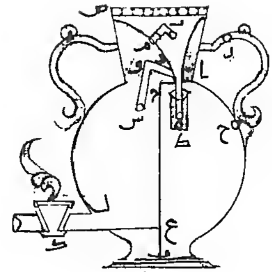

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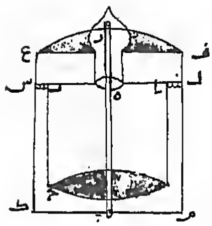

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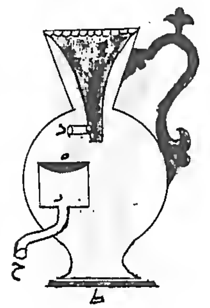

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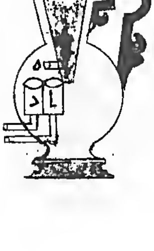

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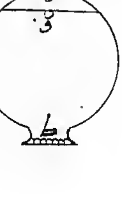

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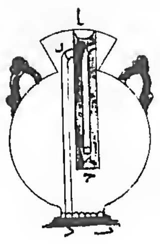

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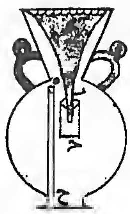

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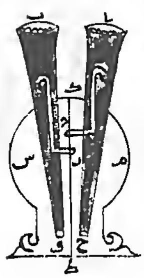

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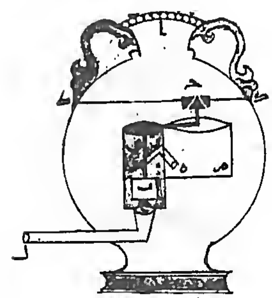

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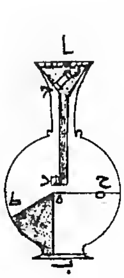

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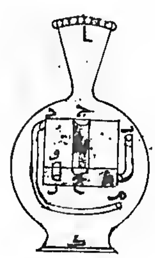

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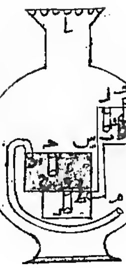

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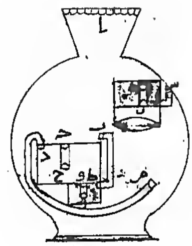

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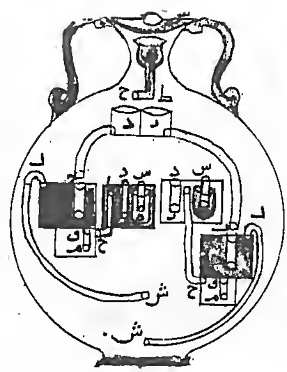

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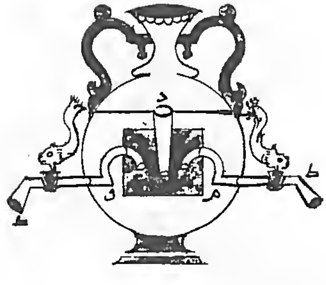

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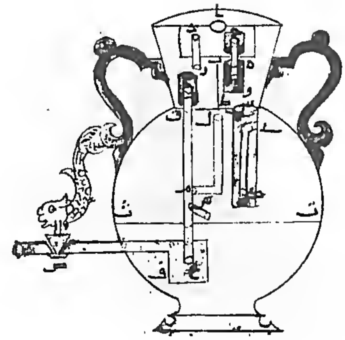

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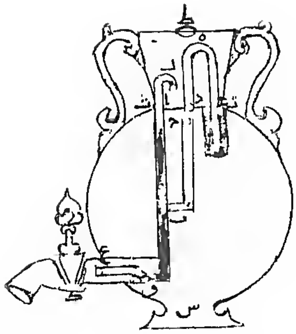

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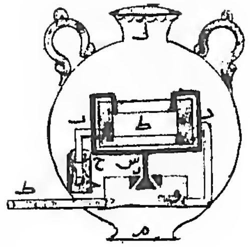

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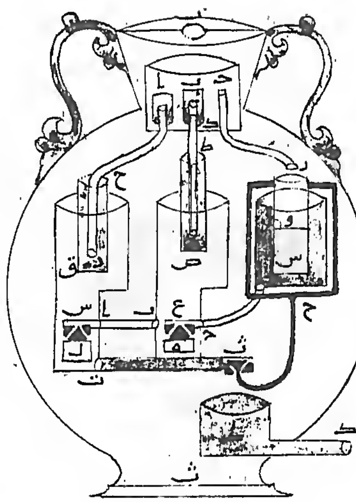

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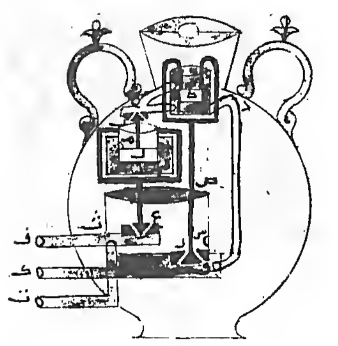

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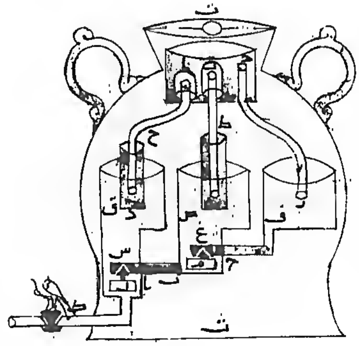

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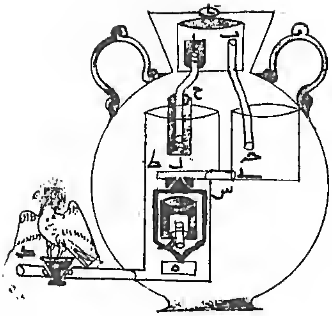

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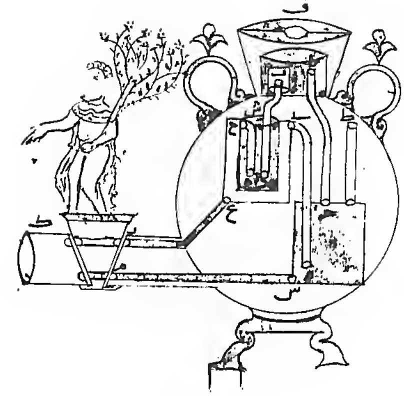

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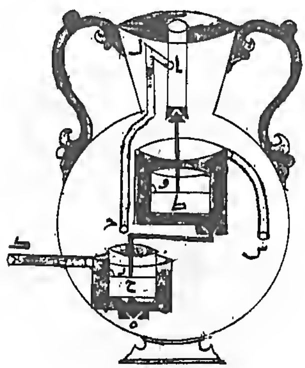

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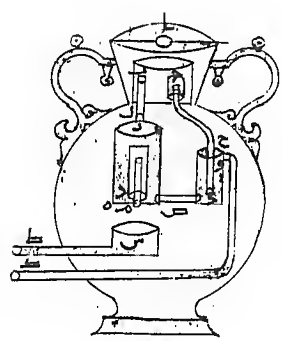

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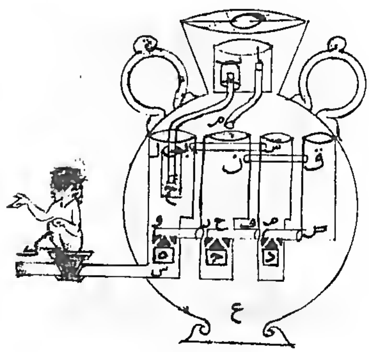

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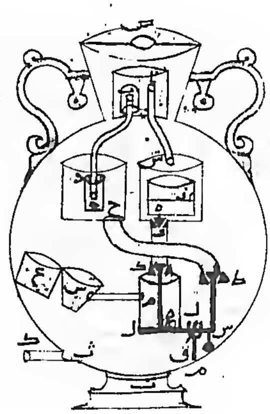

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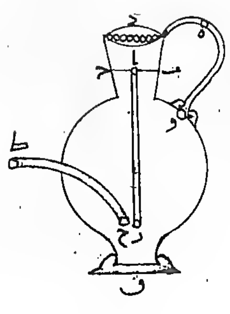

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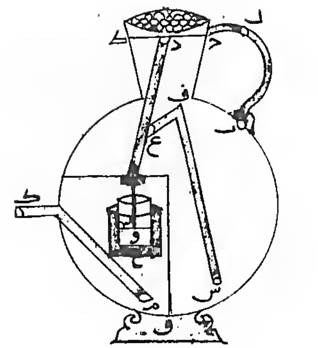

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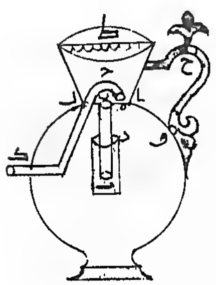

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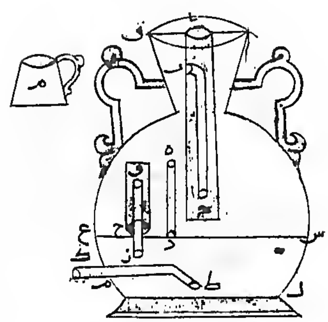

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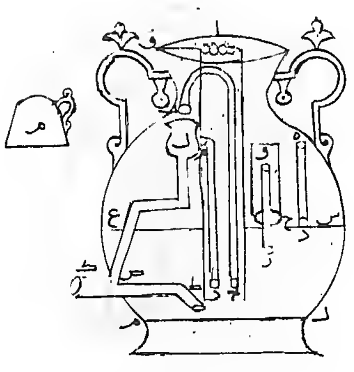

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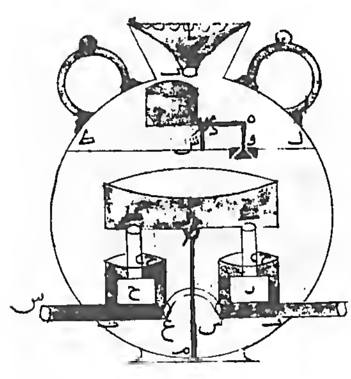

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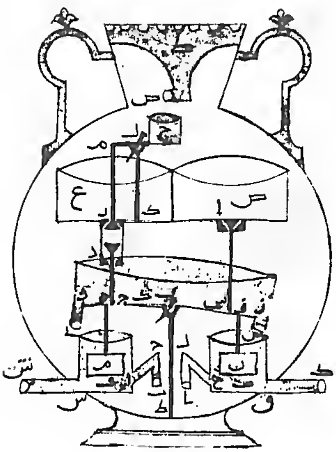

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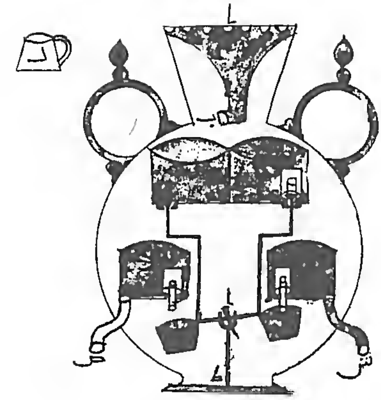

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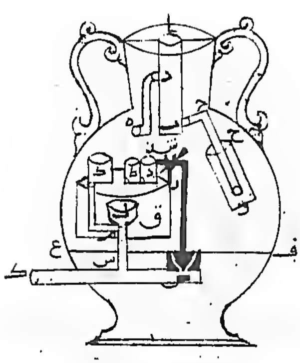

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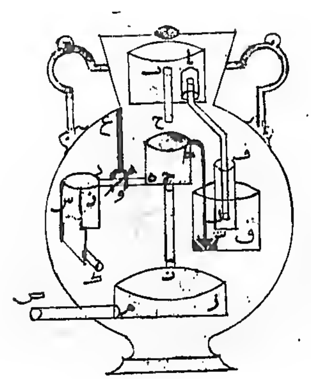

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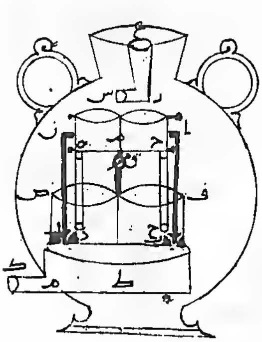

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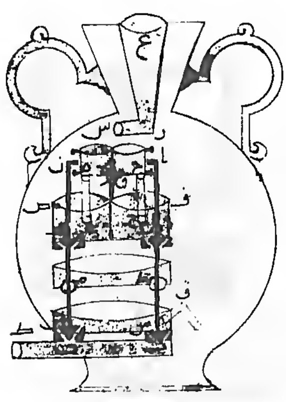

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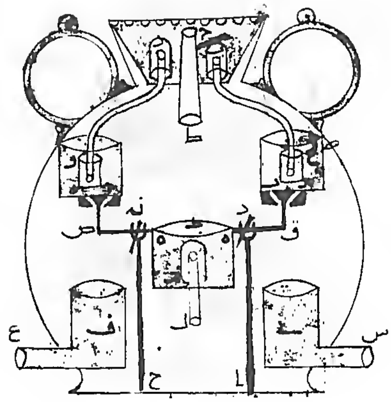

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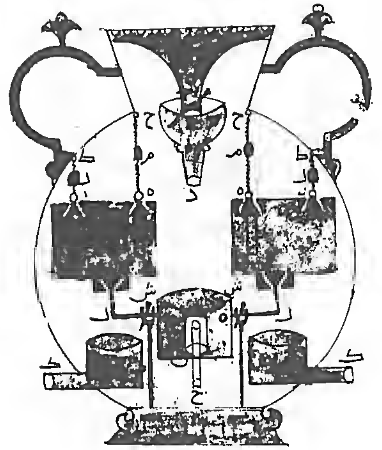

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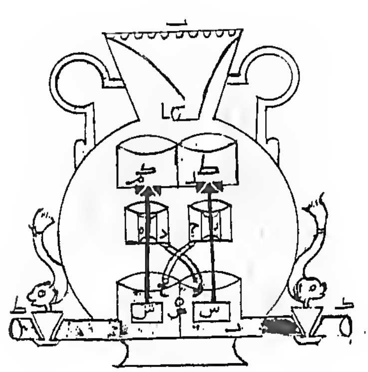

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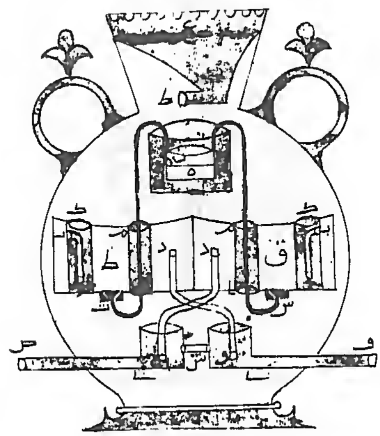

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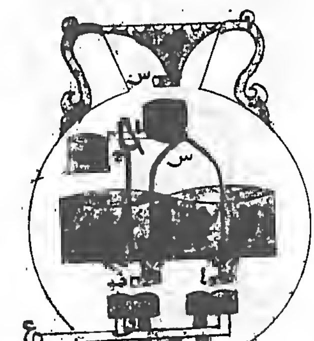

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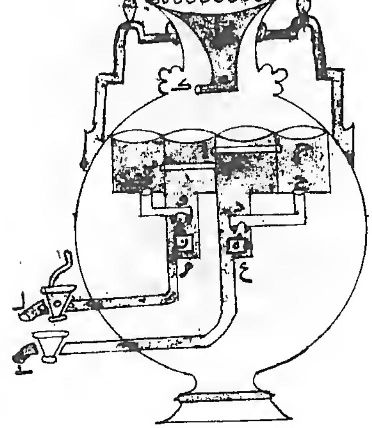

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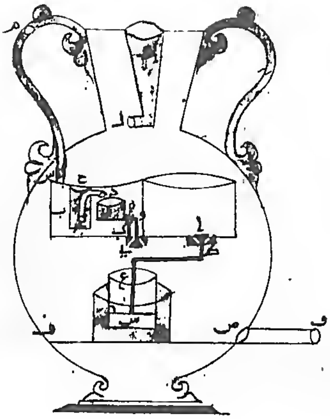

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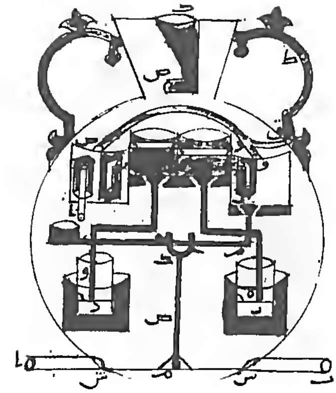

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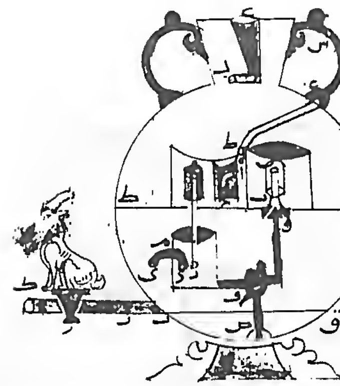

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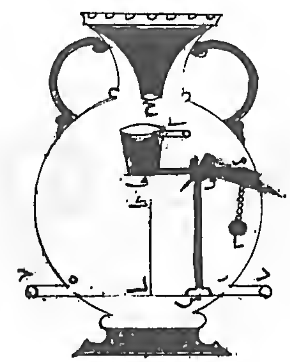

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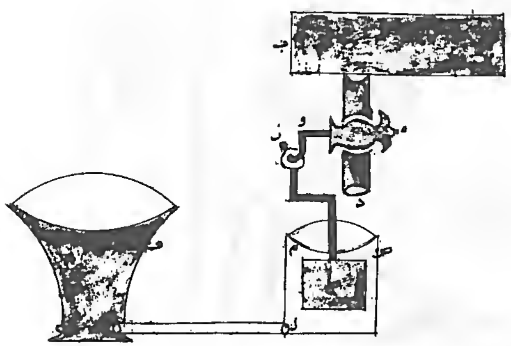

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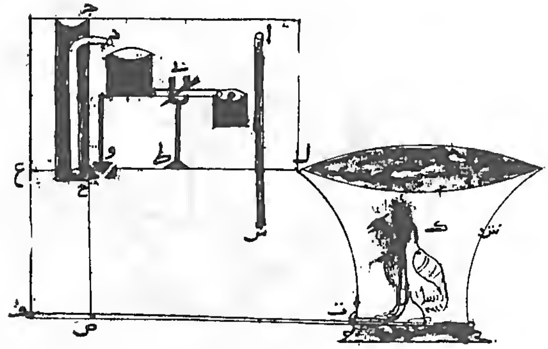

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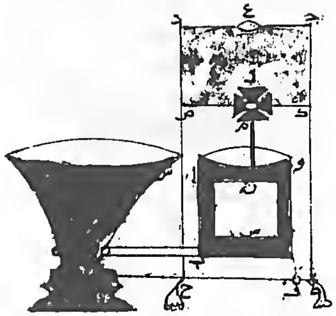

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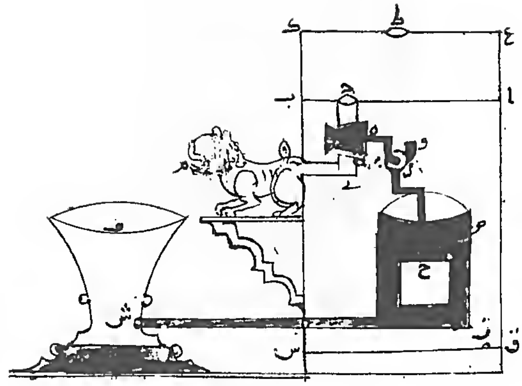

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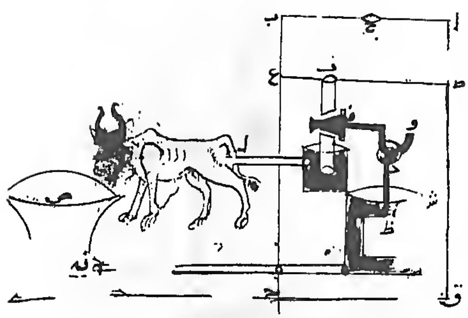

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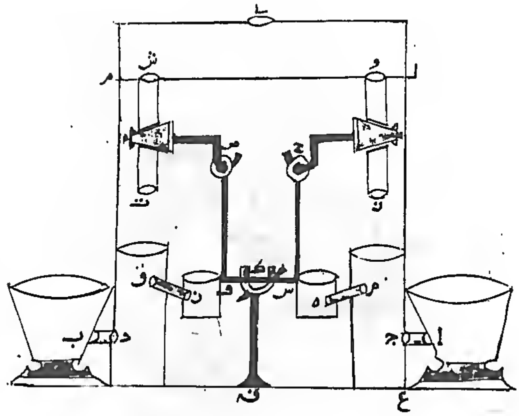

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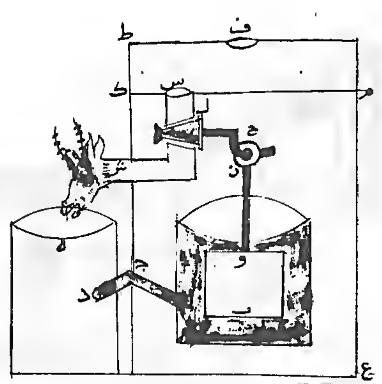

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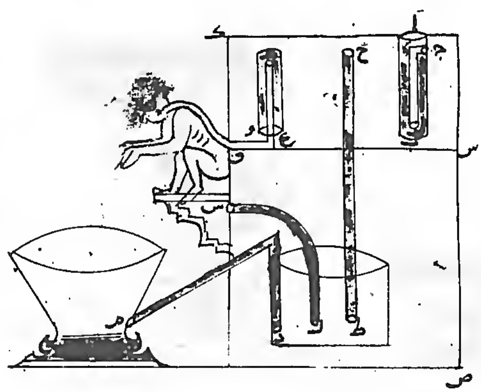

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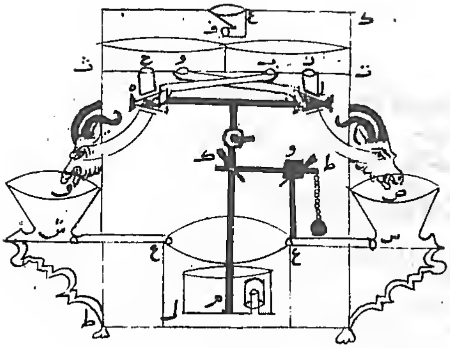

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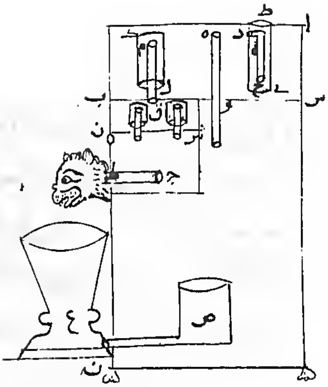

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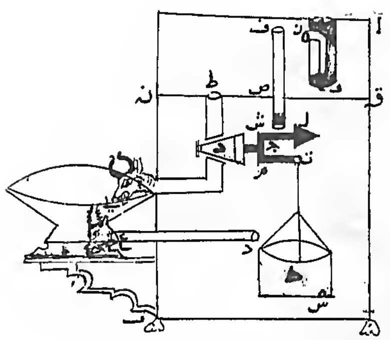

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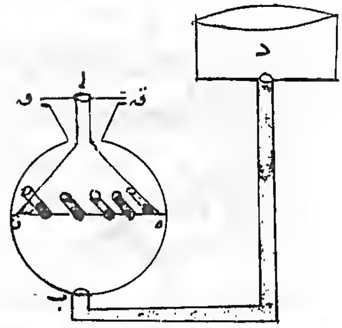

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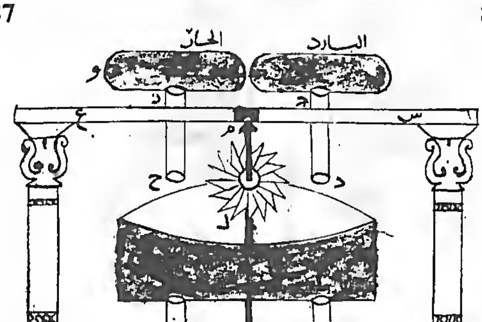

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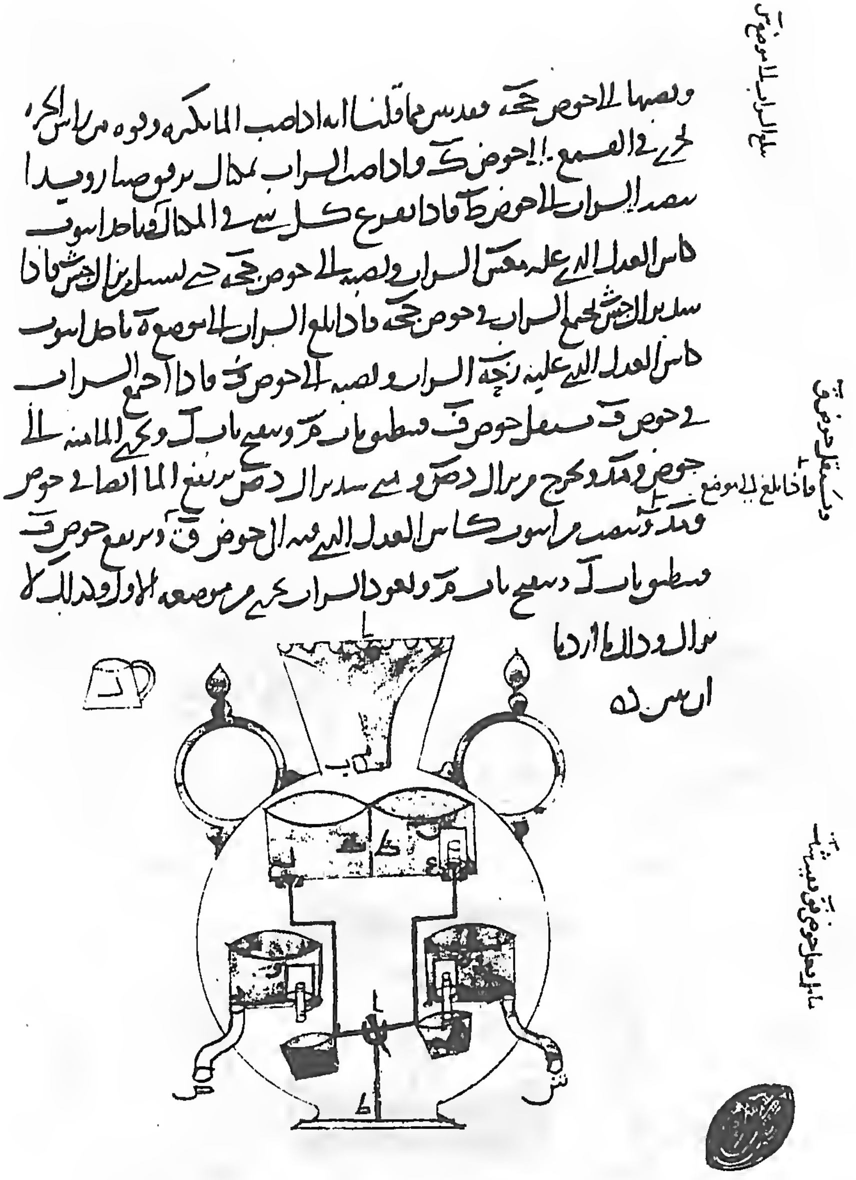

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شكر وتنويه

لقد رأيت من الواجب عليّ هنا ان أنوه بأنني مدين بالكثير الى تشجيع الدكتور كاظم چچن، كما أنني تلقيت كثيرا من الدعم والمساندة من الاستاذ الدكتور أكمل الدين احسان اوغلى، وانتهز هذه الفرصة لأتقدم إليهما بجزيل الشكر. كما أتقدم بالشكر الى العاملين في مركز الابحاث للتاريخ والفنون والثقافة الاسلامية باستانبول الذين تعاونوا معي في اعداد وطبع الكتاب. واشكر كذلك زوجتي لمساندتها، واشكر السيدة مُوجْدِة گوزَلْقَيا لمساعدتي على دراسة النص بعناية وتصحيحه، والسيدة آيْدَان أكْسين لقيامها بطباعة نصوص الكتاب بشكل جيد.

آتيلا بير

استانبول، مارس ١٩٩٠

التي لم ترد في مخطوطة طوب قابى فقد استخرجت من نسخ مخطوطة وجدت في مكتبات الفاتيكان وبرلين وغوته "Bibliotheca Apostolica Vaticana (No:317); Orientabteilung der Staatsbibliothek Preuissischer Kulturbestiz Berlin, Catalogue von Ahlward" (no. 5562); Gotha Catalogue von Pertsch (no. 1349).

ويمكن القول ان الدراسات التي تناولت موضوعات التكنولوجيا والميكانيكا قليلة في العالم الاسلامي، كما هو الحال بالنسبة للعلم القديم. وقد تم دراسة ونشر الاعمال البارزة في هذا المجال من قبل مجموعة من العلماء والمؤرخين المعنيين بتاريخ العلوم. ومن يود التعرف على الوضع الحالي لهذه الجهود يمكنه الاطلاع على بحث حديث قام به الدكتور هيل في مقالته التي لم تنشر بعد تحت عنوان :

Mechanical Technology in Islam-Current State of Research: Autumn 1989.

اضافة الى كتابيه السابقين في نفس الموضوع وهما :

A History of engineering in Classical and Medieval Times, London, 1984. Islamic Technology: an illustrated history, 1986. والكتاب الثاني تم تأليفه بالاشتراك مع احمد الحسن.

هذا التقديم الموجز يوضح المنهج الجديد الذي اتبعه الدكتور اتيلا بير في دراسته، اذ قام بتحليل العلم الاسلامي في العصور الوسطى من وجهة نظر المعرفة العلمية الحديثة.

ويسر المركز ان يقوم بنشر هذا العمل آملاً ان يلقى الاهتمام من قبل الاوساط المعنية، مثل ما سبقه من كتب نشرت ضمن نفس السلسلة، وهي «فهرس مخطوطات الطب الاسلامي في مكتبات تركيا» و «الجمعيات العلمية والمهنية العثمانية» و «فهرس اوائل كتب الكيمياء المطبوعة».

ويطيب لي هنا ان انتهز هذه المناسبة لأتقدم بالتهنئة للدكتور اتيلا بير على مساهماته القيمة في مجال تارخ العلوم، متمنيا له دوام التوفيق، كما اشكر العاملين بالمركز ومطبعته لمساهمتهم في ترتيب واعداد الكتاب وعلى رأسهم الدكتور هدايت نوح اوغلى والزملاء العاملين في وحدة الكمبيوتر.

اكمل الدين احسان اوغلى
مدير عام المركز

ويقع الكتاب في ثلاثة فصول، إذ يتناول الدكتور اتيلا بير في الفصل الاول حياة الاخوة «بني موسى» وعلاقتهم بالخلفاء، ثم يقدم بعض المعلومات عن التصاميم والاجهزة الرائعة، وبالأخص في «كتاب الحيل». اما في الفصل الثاني فهو يستعرض النماذج الأساسية، وفي الفصل الثالث فقد قام بوصف الانظمة.

ويقدم الكتاب النماذج الاولى للعديد من الادوات الميكانيكية والرسوم التقنية ونظم الضبط والادارة، وبالاخص نظم الضبط التلقائي. هذا ويمكننا ان نعتبر الكتاب استمرارا وتطويرا لكتاب «**الآلات الروحانية**» **Pneumatica** الذي ألفه فيلون البيزنطي وكتاب الميكانيكا الذي ألفه هيرون الاسكندري . كما كان تأثير «كتاب الحيل» لبني موسى على المؤلفات التي اعقبته كبيرا وبلغ ذروته في «كتاب الجامع بين العلم والعمل النافع في صناعة الحيل» الذي ألفه بديع الزمان بن الرزاز الجزري في بداية القرن الثالث عشر الميلادي، اذ احتوى عدداً كبيراً من الساعات والاجهزة الاتوماتيكية الاخرى. ويمكن القول ان تكنولوجيا عصر النهضة تدين بالكثير لهذه الاسهامات الرائدة.

وقد جرى بالدرجة الاولى تحليل النماذج المستعملة في الاجهزة المقدمة. ويلاحظ انه قد تكرر استعمال عدد محدود من النماذج التي تشكل الاساس الهيكلي لكل التصاميم. وهذه النماذج تشبه العناصر الموجودة في الدوائر الالكترونية الحديثة، إذ تقوم متعادلات مختلفة من هذه العناصر بتأدية وظائف متعددة داخل الأنظمة، ويتم فحص خصائص العناصر وتطوير نماذج رياضية لها للوصول الى افضل الحلول. ان هذا المنهج ليتفق كثيراً مع اسس التحليل الحديث للنظم. وهذا ما يجعل الكتاب طريفا، وخاصة للمهندسين.

يتناول الدكتور اتيلا بير الاجهزة في هذه الدراسة، فيُوسِعها بحثا، معتبرا كل واحد منها نظاماً منفصلاً. فيحدد في البداية النماذج المستعملة في انواع الاجهزة، ثم يجمع الانواع استناداً الى علاقات منطقية متعددة، وعلى وحدات خطية وغير خطية، فيحصل منها على الرسومات المتطابقة للوحدات، ويطور بواسطتها نموذجاً رياضيا لتقدير اعمال النظم وتفسير طريقة عملها.

اما الرسوم التوضيحية المتعلقة بالنماذج فقد استخرجت من مخطوطة الكتاب المحفوظة في مكتبة متحف سراي طوب قابي، تحت رقم **(A. 7374)**. وهي أقدم واكمل نسخة مخطوطة للكتاب، وهي التي تعتمد عليها الطبعة الحالية لهذا الكتاب. ام الرسوم والنماذج

مقدمـة

تصدر عن مركز الابحاث للتاريخ والفنون والثقافة الاسلامية باستانبول دراسة عن «كتاب الحيل» ضمن سلسلة «دراسات ومصادر تاريخ العلم». ويعد هذا الكتاب واحدا من ابرز الاسهامات التي اضطلع بها المسلمون في الماضي في مجال العلوم الميكانيكية. وفي هذه الدراسة يقوم الدكتور اتيلا بير بتفسير وتحليل «كتاب الحيل» الذي ألفه بنو موسى بن شاكر، وذلك من وجهة نظر النظم الحديثة وهندسة التحكم.

و«كتاب الحيل» عمل طريف حول المصابيح السحرية وميكانيكا التحكم الذاتي ومصابيح الزيت والنوافير. وقد اهتم به كل من هاوسر و فيديمان، فقاما بترجمة قسم منه. وكان Otto Mayr قد اشار قبل ذلك الى اهمية الكتاب واصالته. اما الدكتور دونالد هيل فقد قام بترجمته ترجمة كاملة، واجرى عليه دراسة واسعة. ثم قام اخيرا الدكتور احمد الحسن بتحقيق النص الكامل لكتاب الحيل والتعليق عليه، وصدر عن معهد التراث العلمي العربي بجامعة حلب عام ١٩٨١. ويمكننا القول من خلال مخطوطات الكتاب الناقصة والموجودة حالياً في مكتبات متعددة، بوجود مايزيد على مائة نظام في النسخة الاصلية.

وقد كان محمد واحمد والحسن من العلماء الذين ذاعت شهرتهم باسم «بني موسى»، وعاشوا في بغداد في القرن التاسع الميلادي، وشهد لهم الناس بانهم كانوا أعلاماً مبرزين في حقل العلوم الرياضية في عصر العباسيين. ومن الشائع بصفة عامة ان احمد الذي كان اشد اهتماما بموضوعات الميكانيكا هو الذي ألف الكتاب المذكور.

ويتناول «كتاب الحيل» مائة جهاز، جرى التعليق عليها وشرح أغلبها بصورة وافية. ويمكن تقسيمها كما يلي: ثلاثة وسبعون جهازاً عن الأواني السحرية، وخمسة عشر جهازاً للتحكم الذاتي، وسبعة نوافير ماء، وثلاثة مصابيح زيت، ونظام واحد لميكانيكا الرفع. وتستند طرق عملها بصفة عامة على مبادىء الضغط الايروستاتي والهيدروستاتي. وتعد هذه الانظمة اكثر تقدماً اذا ما قيست بمثيلاتها الهيلينية، بل إن بعضها يمكن ان يلبي متطلبات الميكانيكا في العصر الحاضر.

مركز الابحاث للتاريخ والفنون
والثقافة الاسلامية (ارسيكا)

سلسلة دراسات ومصادر
تاريخ العلم – ٤

تصدر تحت إشراف
اكمل الدين احسان اوغلى

مركز الابحاث للتاريخ والفنون والثقافة الاسلامية باستانبول
(ارسيكا)

« كتاب الحيل »
لبني موسى بن شاكر

تحليل هندسي عصري على ضوء الانظمة الحديثة

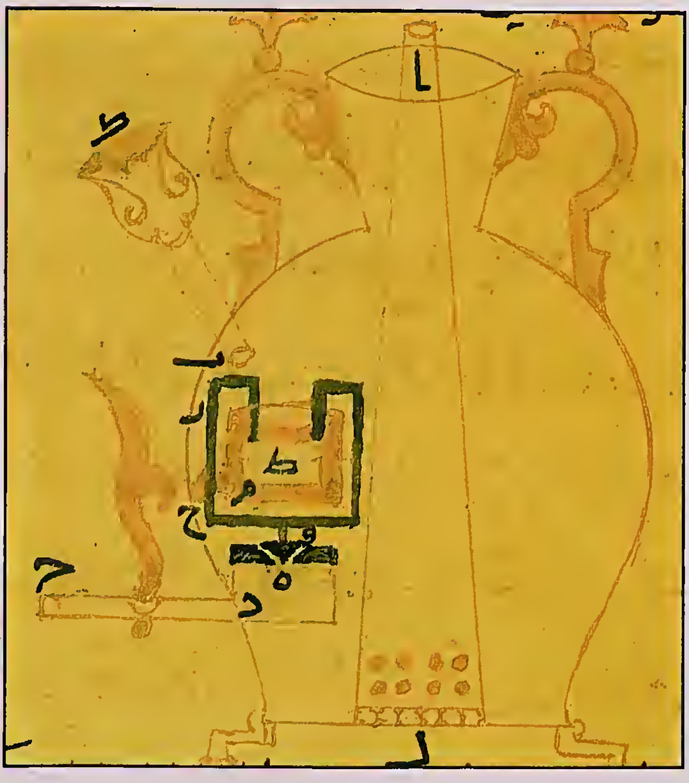
اتيلا بير

استانبول
١٤١٠هـ - ١٩٩٠م

Works dealing with technical and mechanical subjects are few in islamic science.

*This new publication of **IRCICA** highlights one of the outstanding muslim contributions of the past in the field of mechanical sciences. In this work Dr. A. Bir interprets and analyses **Kitāb al- Ḥiyal** from the point of view of modern systems and control engineering. This is an interesting work on magic cups, automatic control mechanisms, oil, oil lamps, fountains, a bellow and an elevator.*

This work reflects a new approach and methodology in the history of science studies. It analyses medieval islamic science from the viewpoint of modern scientific knowledge.



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"KITĀB AL-ḤIYAL" OF BANŪ MŪSĀ BIN SHĀKIR